Packet Data Radio

Installation and Operation Manual

PDR 121

RADIUS

RADIO NETWORK TECHNOLOGY

Contents

1 General

1.1 Document History

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Valid from: 2004-10-13

Latest Update: 2004-12-10

Approved: Anders Grahn

Template revision: 01, 001024

Revision	Date	Updated by	Amendment
01	2004-10-13	Arto Valtonen	First revision
02	2004-12-10	Arto Valtonen	Second revision, added new configuration menus - 'Advanced'

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2 Find Your Way in The Manual

Chapter 3 gives an *introduction* to Radius PDR 121 system and some *application examples*.

Chapter 4 contains *technical specifications* for the PDR 121.

Chapter 5 provides a *Quick Start Guide* for installation and configuration of the PDR 121

Chapter 6 contains a *Glossary of Terms.*

Chapter 7 describes the *basic and extra features* of the PDR 121.

Chapter 8 describes how *the PDR 121 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 PDR 121 configuration menus* and how to set the different *parameters*.

Chapter 13 contains *radio network configuration examples.*

Chapter 14 describes the *PDR 121 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 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 PDR 121, Packet Data Radio 121, transceiver provides wide range data telemetry for control and monitoring systems using the DNP3, IEC870 COMLI or RP570 protocol. The transceiver is designed for point-to-multipoint operation environments including water, wastewater, electric utilities, distribution automation, and gas field automation.

A PDR 121 system consists of one master and up to 99 slave radio units. Each slave radio can operate as a repeater, stand-alone or with an RTU device connected. A message can be repeated via up to six radios, 7 hops, to reach its destination. This gives a total coverage area of at least 200 km radius from the master.

The PDR 121 data radio is suitable for both polled and unsolicited systems. For unsolicited systems, there is a 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, which means all data is buffered before/after transmitting/receiving on the radio. 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 increases the radio sensitivity.

Routing of messages across the radio network is achieved by configuring the RTU addresses and the Radio id's in the PDR 121 Network menu. Messages are routed to the radio that is connected to the destination address along the configured radio path. The radio network paths are easily configured in the radio using a handheld terminal or a PC.

The control/monitoring device is connected to the PDR 121 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 PDR 121 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 SME's 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 dialled 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
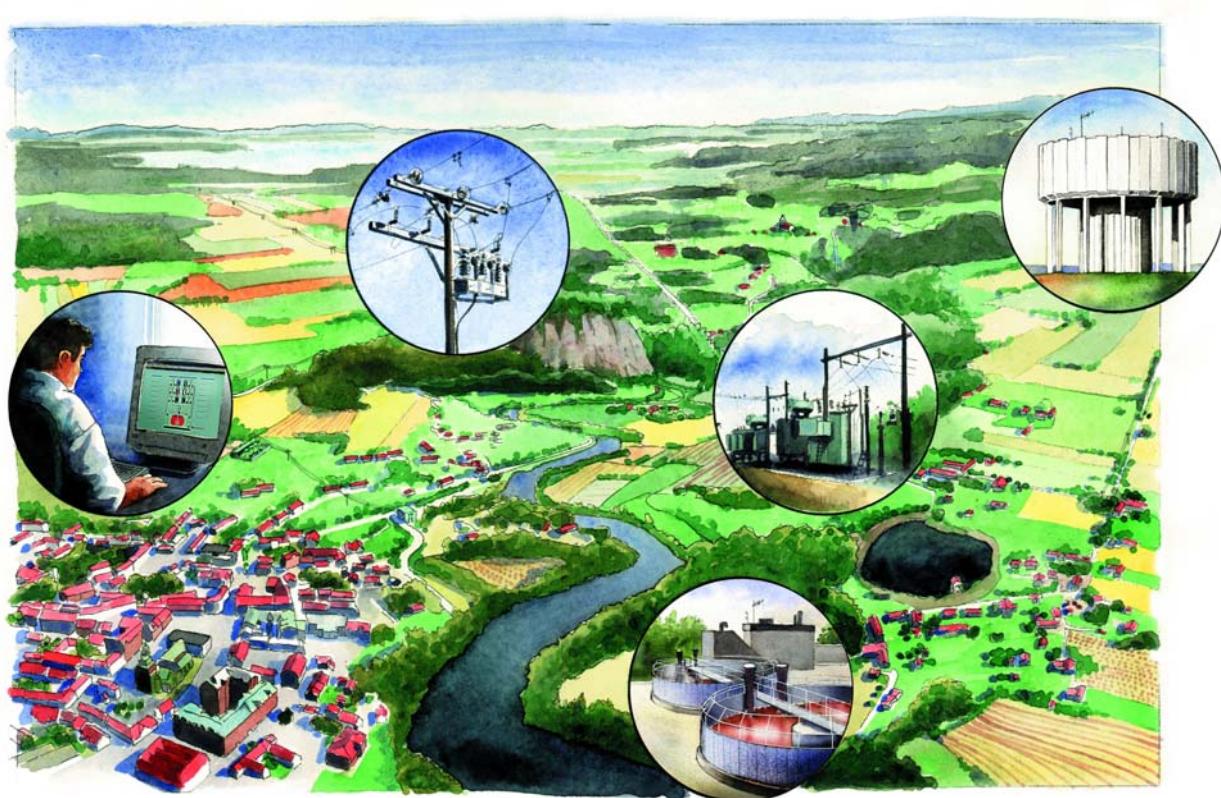
3.1.1 Examples Of Typical Application Networks

3.1.1.1 Point-to-Point
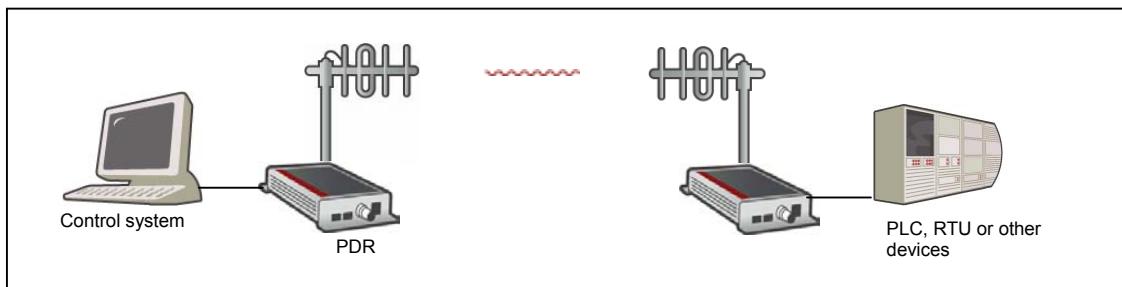
3.1.1.2 Point-to-Multipoint
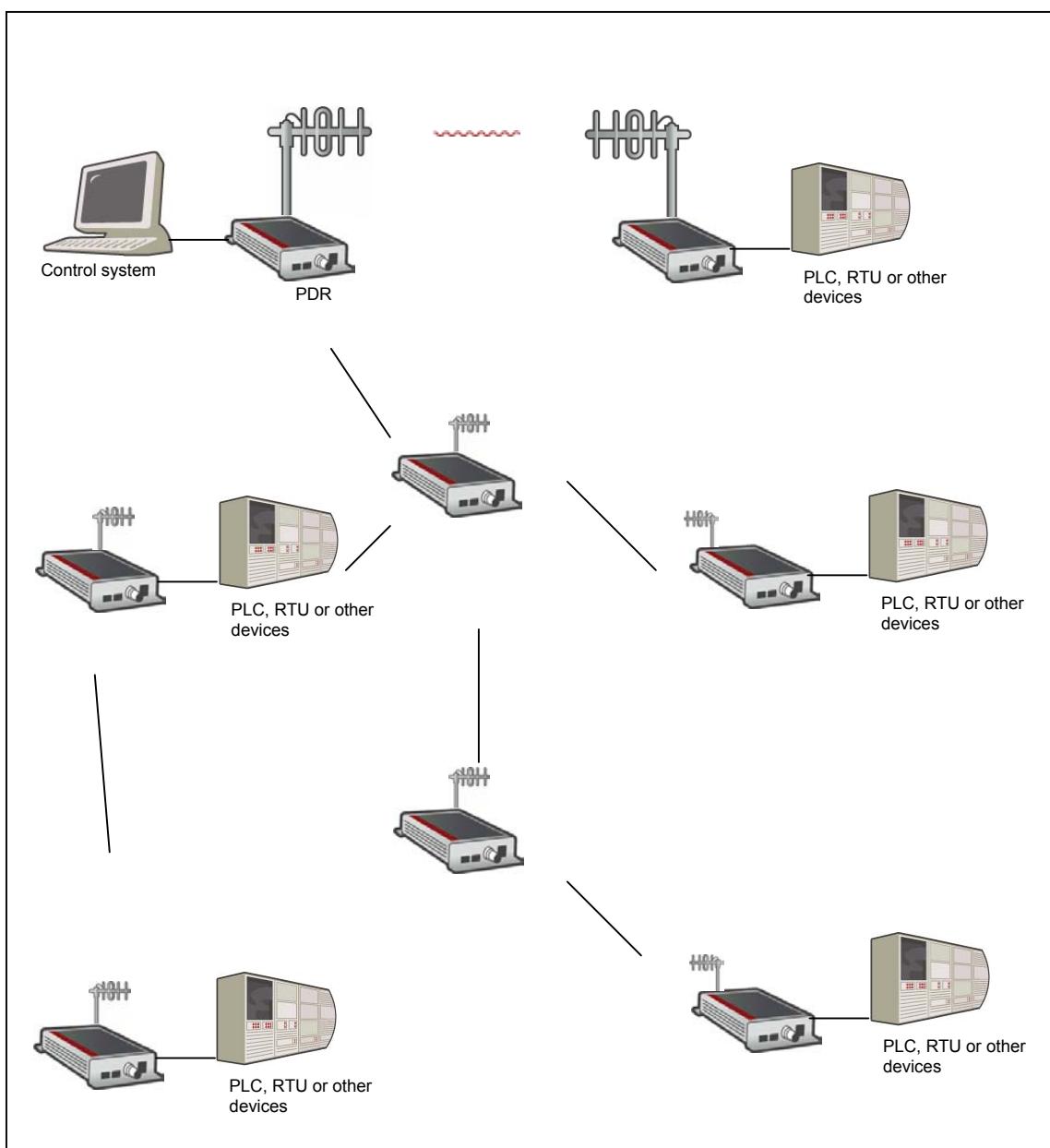
3.1.1.3 Water/Wastewater Network
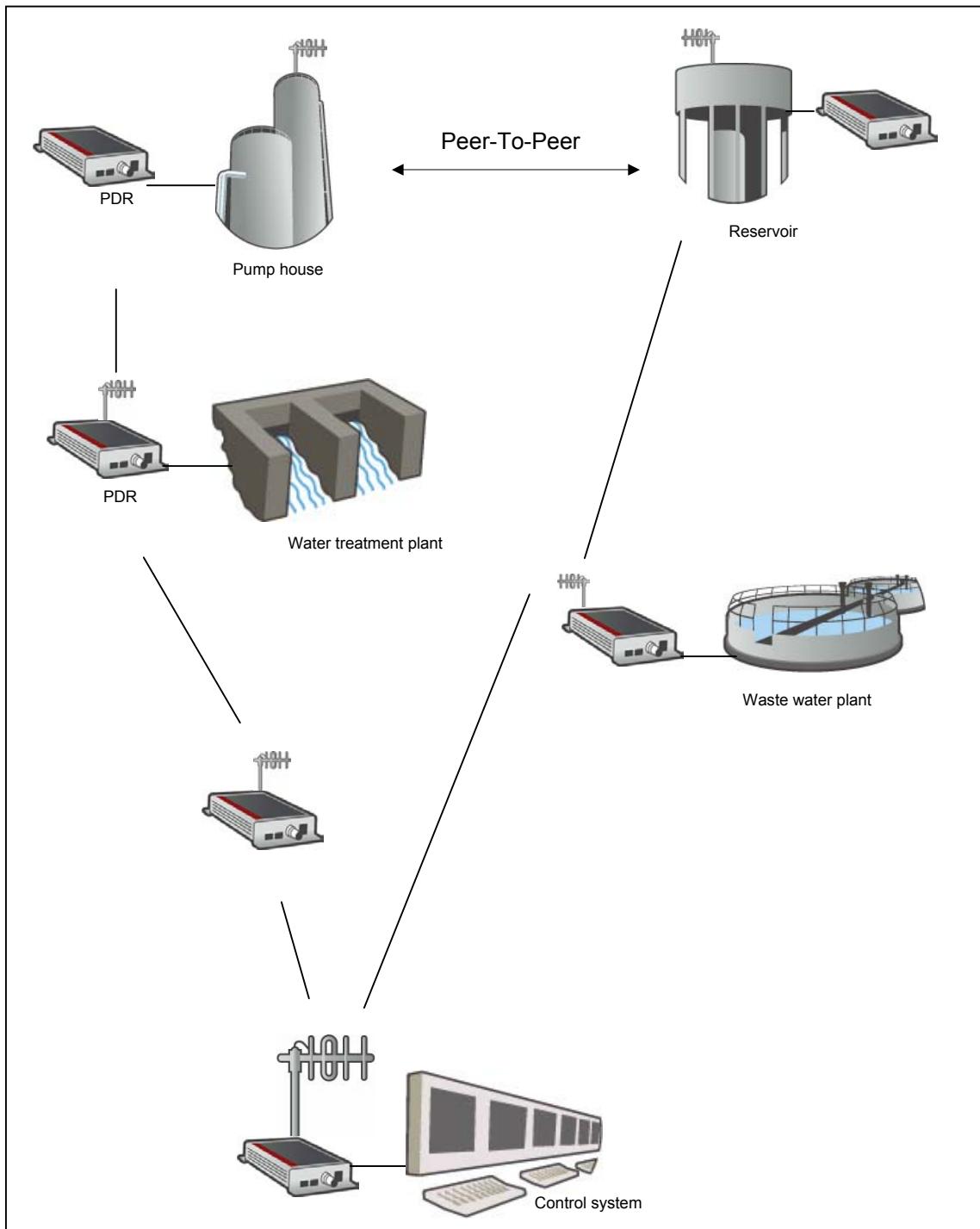
The example above shows two substations communicating Peer-To-Peer.

3.1.1.4 Electrical Distribution Network

Recloser

Metering points

Substation

Substation

Capacitor switch

Control system
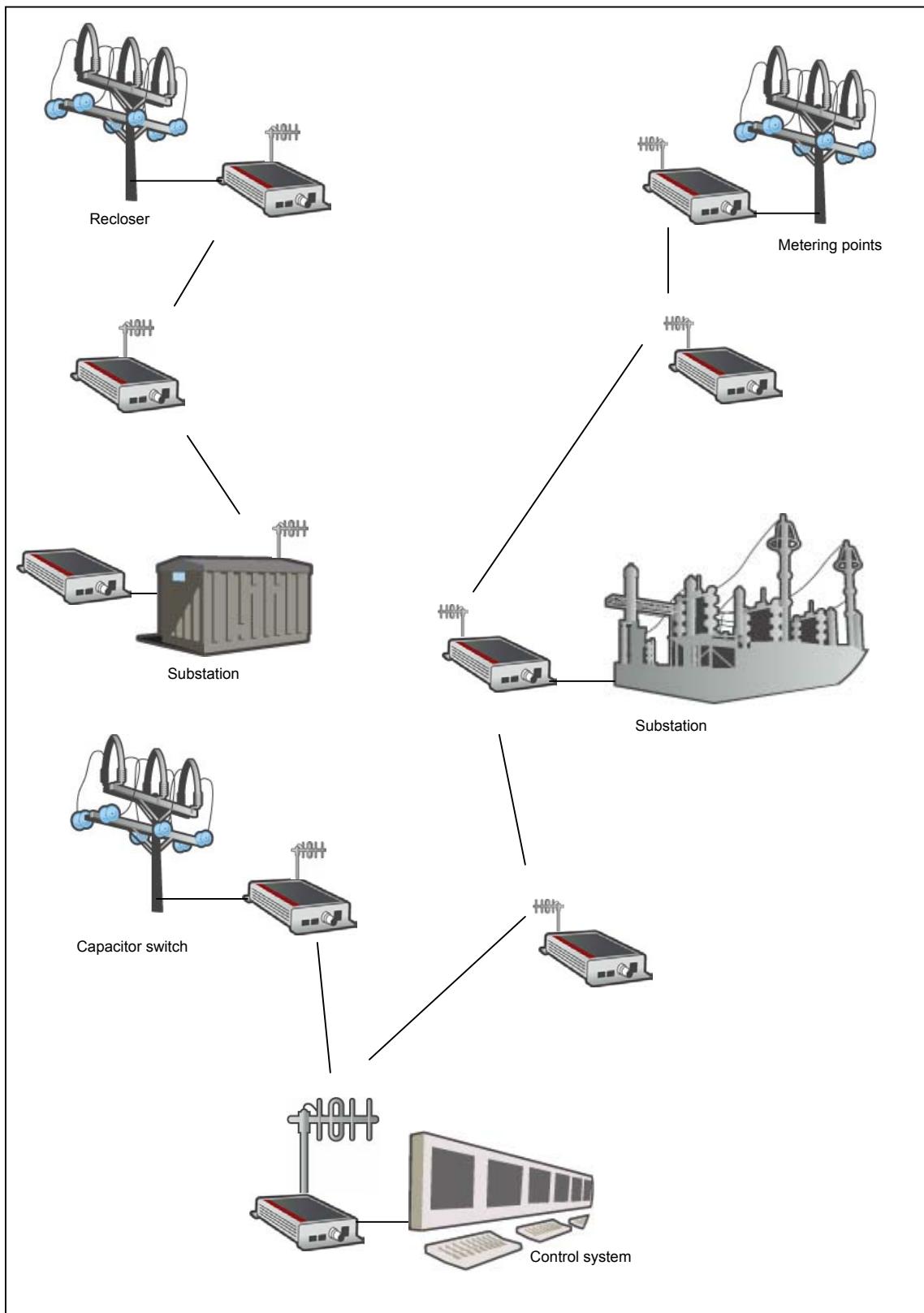
4 Technical Specifications

Radio Transceiver

Data Rates	4800…19200 bps
Frequency Range	UHF 403..470 MHz. VHF 132…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	Multi-Repeating. Up to 6 repeaters on one link.
No of remote radios per master	99
Compliances	ETSI 300220, ETSI 300113, MPT1411, FCC

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

Serial Interface – RS232	Three wire, Rx/Tx/GND
Data Rates	600…19200 bps
Flow Control	DCD/CTS flow control signals selectable.

Protocols	DNP3, IEC870, RP570, COMLI

Power Supply

Operating voltage	10…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, Female, 3.81 mm split
Battery Supply	2-pole, 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

PDR 121 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.

PDR 121 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 PDR 121 in to the RTU cabinet. / Install the PDR 121 cabinet. See chapter 9.

3. Connect the antenna cable, ground wire, RS232 cable and power supply to the PDR 221. See chapter 9.

4. Configure the PDR 121 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. System ID   (Menu 1. Network)
   b. Radio ID   (Menu 1. Network)
   c. RTU address(es)   (Menu 1. Network)
   d. Radio path (if repeaters used)   (Menu 1. Network)
   e. RS232 (serial) parameters   (Menu 2. Serial)

5. Perform Radio Link Test to all adjacent units. (Menu 3. Radio). See chapter 14.3.

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

7. The PDR 121 unit is now ready for operation.
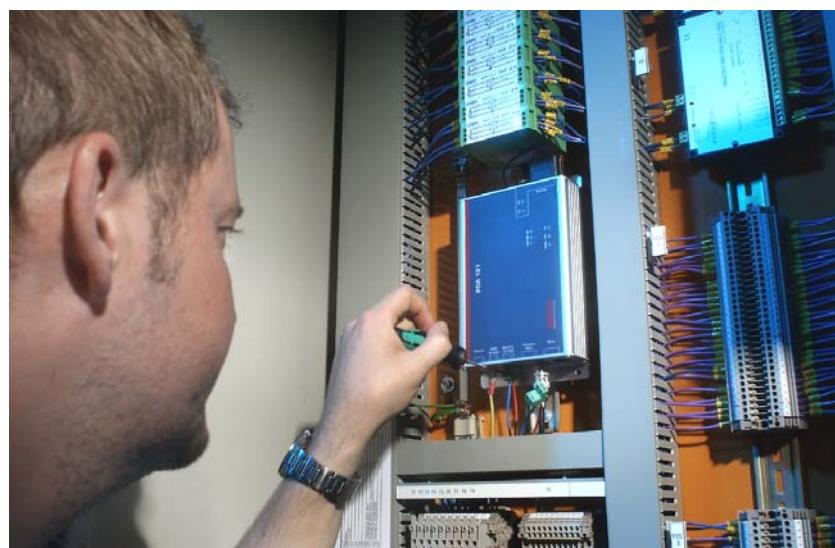
6 Glossary Of Terms

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 PDR 121.

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 which 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…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; each RTU has its own address in the radio unit network list.

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 either 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 an 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 – 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 PDR 121 Radio Transceiver Functionality

This chapter describes the PDR 121 radio functionality.

7.1 PDR 121 Operation Blocks

The figure below shows the basic building blocks of the PDR 121.
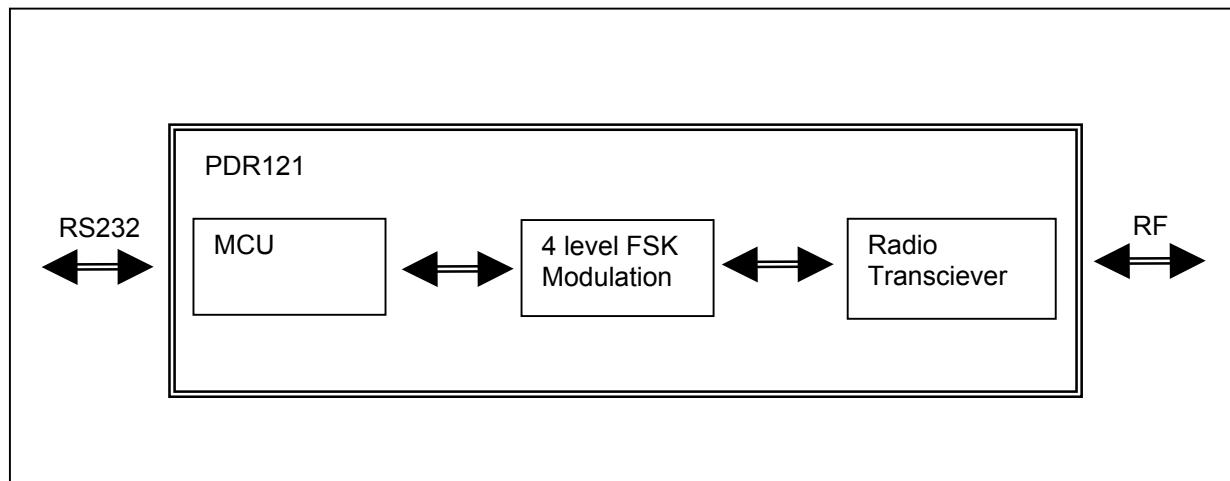
RS232 to RF
Serial data is received on the serial port. The MCU, (Micro Controller Unit), analyses the data and frames the data and transfers it to the modulation unit. (The complete message is buffered in the processor memory before being transmitted). The modem unit converts the received bit stream 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 non-acknowledge message (NACK) 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 Communication

The PDR 121 can act as a master or a slave/repeater in the system. The routing information, RTU addresses, radio identities and repeater paths, are configured in each radio unit.

When the connected control system transmits a telegram to the master, the master reads the telegram address, i.e. the destination. The master compares the address to the configured network routing table to check if there is a (slave) radio ID tied to the telegram address. If there is, the master checks if the telegram shall be transmitted via any repeaters Finally the master radio transmits the telegram to the slave via repeaters, if any. A reply back to the master is performed in the same manner.

Example 1: Telegram from master to slave 7

The master receives a telegram from the connected control system	The master transmits the telegram via radio	Slave 7 receives the telegram and transmits it to the control led system (RTU or IED)
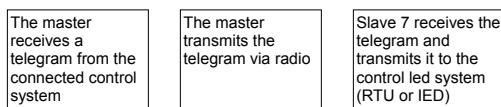
Example 2: Telegram from master to Slave 5 via the repeaters 1, 2, 3 and 4

The master receives a telegram from the connected control system	The master transmits the telegram via radio	Repeater 1 receives and transmits the telegram via radio	Repeater 2 receives and transmits the telegram via radio	Repeater 3 receives and transmits the telegram via radio	Repeater 4 receives and transmits the telegram via radio	Slave 7 receives the telegram and transmits it to the connected device

Slave 1　Slave 6　Slave 5

Master　Slave 3

Slave 2　Slave 4

Slave 7

Figure 1. Example of signalling procedure.

7.5 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.

Using gain antennas or increasing the output power of the transmitting radio can compensate for the radio receiver sensitivity. 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.

7.5.1 PDR 121 Receiver Sensitivity

Model	Frequency Range [MHz]	Channel Bandwidth [kHz]	Radio Data Speed [bps]	Sensitivity BER < $1x10^{-6}$
PDR 121-A	VHF 132-150	12.5	4800 / 9600	-111 dBm / - 109 dBm
PDR 121-B	VHF 132-150	25	9600 / 19200	-114 dBm / - 107 dBm
PDR 121-C	VHF 150-174	12.5	4800 / 9600	-111 dBm / - 109 dBm
PDR 121-D	VHF 150-174	25	9600 / 19200	-114 dBm / - 107 dBm
PDR 121-E	UHF 435-450	12.5	4800 / 9600	-110 dBm / -107 dBm
PDR 121-F	UHF 435-450	25	9600 / 19200	-110 dBm / -103 dBm
PDR 121-G	UHF 450-470	12.5	4800 / 9600	-110 dBm / -107 dBm
PDR 121-H	UHF 450-470	25	9600 / 19200	-110 dBm / -103 dBm

7.6 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).

7.7 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 12.7.6.

The PDR 121 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.
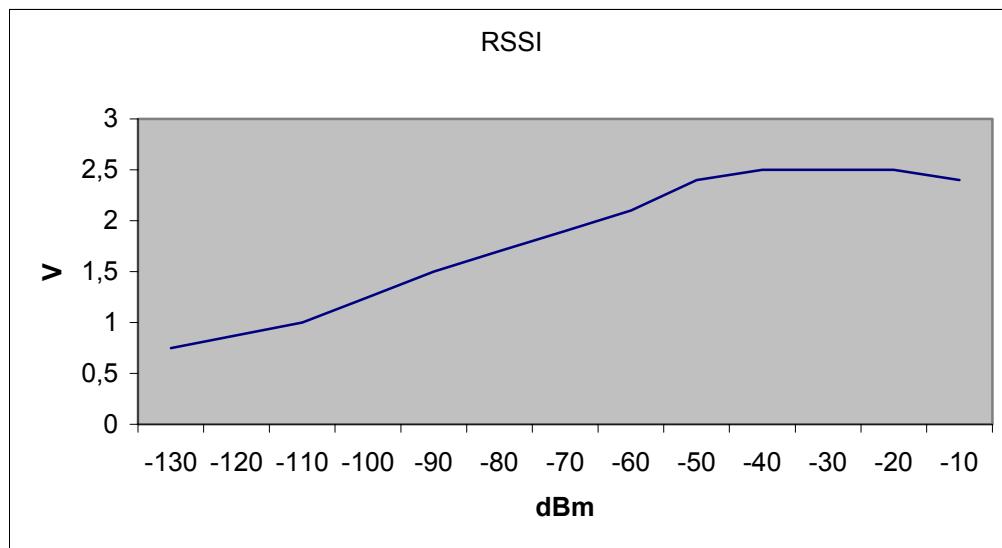
Figure 2. RSSI

7.8 Differences between PDR 121 Models

All models of the PDR 121 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
PDR 121	132-150	12.5	4800/9600	305154-9
PDR 121	132-150	25	9600/19200	305155-8
PDR 121	150-174	12.5	4800/9600	305156-7
PDR 121	150-174	25	9600/19200	305157-6
PDR 121	403-422	12.5	4800/9600	305164-7
PDR 121	403-422	25	9600/19200	305165-6
PDR 121	435-450	12.5	4800/9600	305158-5
PDR 121	435-450	25	9600/19200	305159-4
PDR 121	450-470	12.5	4800/9600	305160-1
PDR 121	450-470	25	9600/19200	305161-0

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

8 Operating the PDR 121

8.1 LED Indicators and Connectors
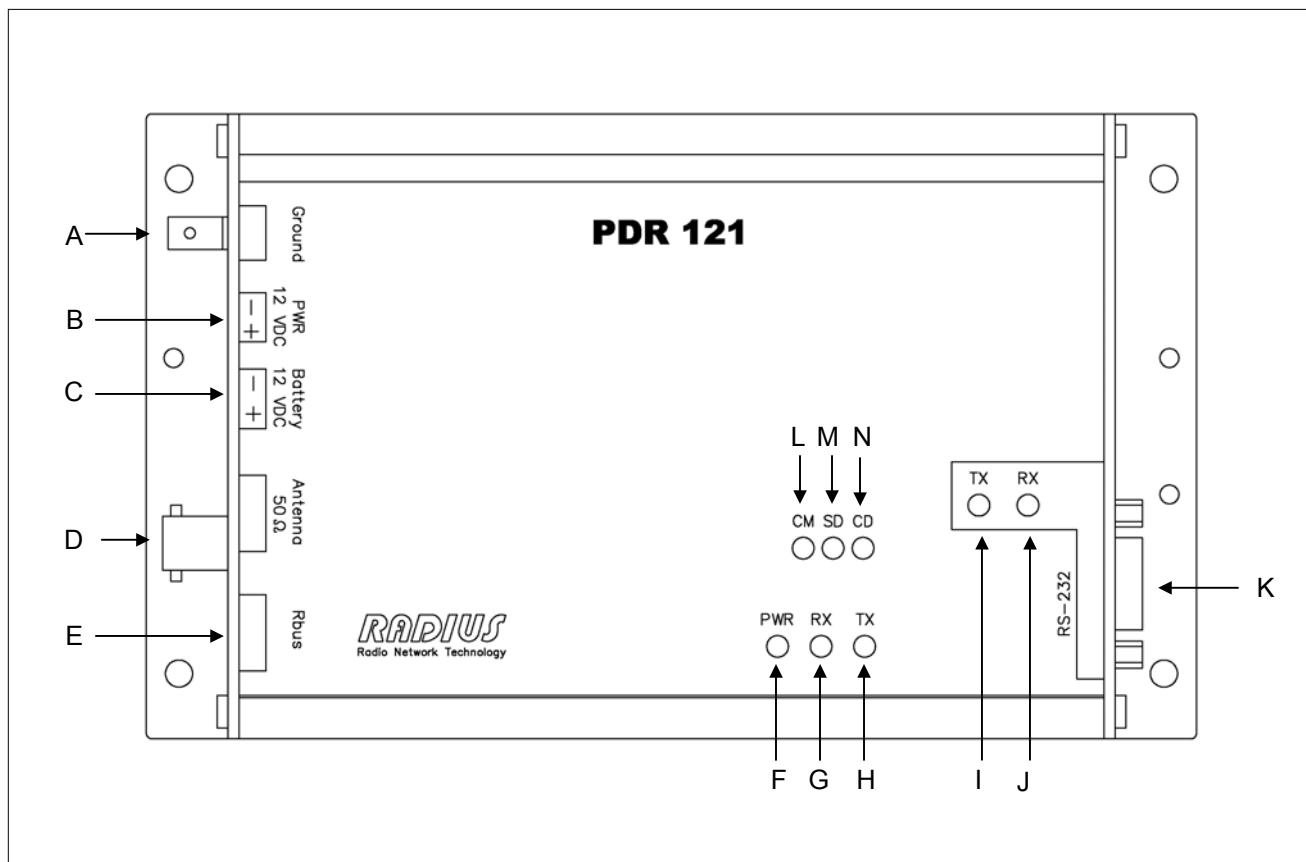
Figure 3. Packet Data Radio 121.

	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 PDR 121 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 121 does not charge batteries via the battery connection jack. See chapter 9.3.

8.2 Peer-To-Peer

The PDR 121 offers the feature of peer-to-peer communication. Any PDR 121 unit can communicate with another, independently from a master unit.

Peer-To-Peer communication is achieved by entering the Peer destination address in the network configuration menu. See chapter 12.5.

Note! The control system and the protocol used must support Peer-To Peer communication. Check this with your control system supplier or contact RADIUS.

8.3 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 PDR 121 is used to minimize the risk of collisions at simultaneous and cascading events on a RTU network.

The basic strategy is that the PDR 121 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 12.7.

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 PDR 121.

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

8.4 Remote frequency change

The PDR 121 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 as described below. The frequency change should always be performed from the master site since the routing information in the network list is used.

See the example printout below.

1. The user is asked to enter new Rx and Tx frequencies. If separate Rx and Tx frequencies (split uplink) are to be used, the new master Rx and Tx shall be entered, see 12.8.12.1.

2. The radio then transmits the new frequency information to all units on the network, one by one, and asks them to perform a frequency lock test on the new frequency. The result from each unit is displayed on the screen. (The remote radios have not yet changed to the new frequencies).

3. The user can then choose to abort or continue.

4. If the frequency change is continued, the remote radio units are asked to change to the new frequency and an acknowledgement is requested. **Note!** The remote units will not switch to the new frequencies until after 20 seconds. This delay is so the master radio can execute re-transmissions to units not responding to the frequency change request.

    The frequency change is executed by starting with the most distant units on the network i.e. the ones using repeaters. Scanning the local network list does this.

5. A communication test is performed to all remote units on the network and the results are displayed.

```
System Frequency Change

New Local Rx Frequency: 442000000
New Local Tx Frequency: 442000000

Test for VCO lock on remote units:
Radio ID          Rx                Tx                Tx Uplink
02                Passed            Passed            NA
03                Passed            Passed            NA

Do you want to proceed and change frequency y/n?

Change Frequency on remote units:
Radio ID          Result
03                OK
02                OK

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

Test communication with remote units on new frequency:
Radio ID          Result
02                Passed
03                Passed

Press any key to continue...
```

8.5 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 12.8.13.

The Tx power setting can be read from any radio on the network by executing the Radio Link Test. See chapter 12.7.6.

8.6 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 PDR 121 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.

8.7 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 14.3.

8.8 Split transmitting and receiving frequencies

If desired, the PDR 121 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 8.9.

8.9 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.

8.9.1 Split Tx Uplink Example Network
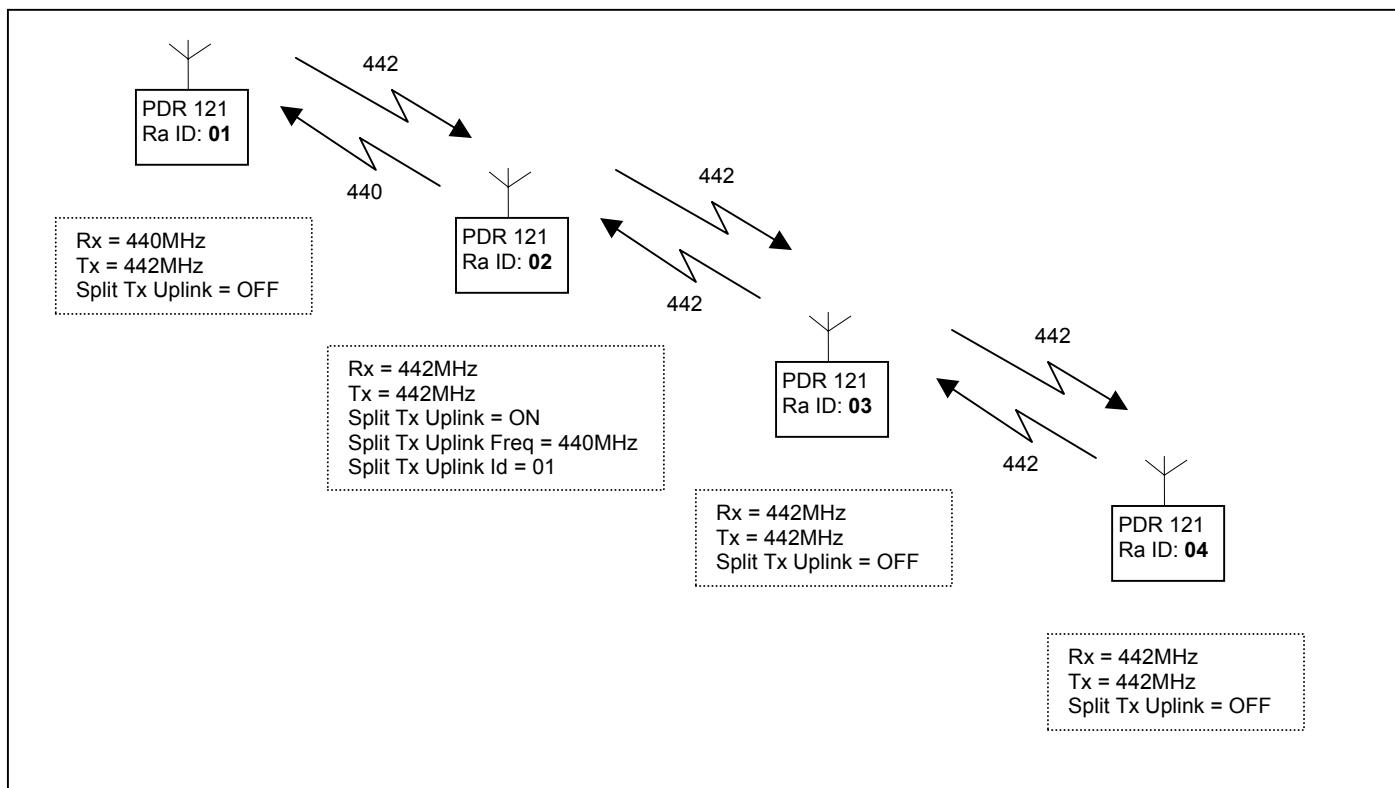
The figure above shows an example of a small Split Tx Uplink network. The dashed boxes shows the configuration of each radio.

The PDR 121 with Ra ID 02 will transmit on 440 MHz when transmitting RTU messages and repeating to the master. (Uplink). When repeating from the master (downlink), the transmit frequency is 442 MHz.

If a system frequency change is performed on this network, the new master frequencies are entered at the master. For example Rx = 445 MHz, Tx = 450 MHz. The result of the frequency change will be:

RaId	Rx Freq [MHz]	Tx Freq [MHz]	Split Tx Uplink	Split Tx Uplink Freq [MHz]	Split Tx Uplink Id
01	445	450	OFF	-	-
02	450	450	ON	445	01
03	450	450	OFF	-	-
04	450	450	OFF	-	-

8.10 Repeating Alternative Systems

Normally, a PDR121 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 12.5.4 for configuration of this feature.
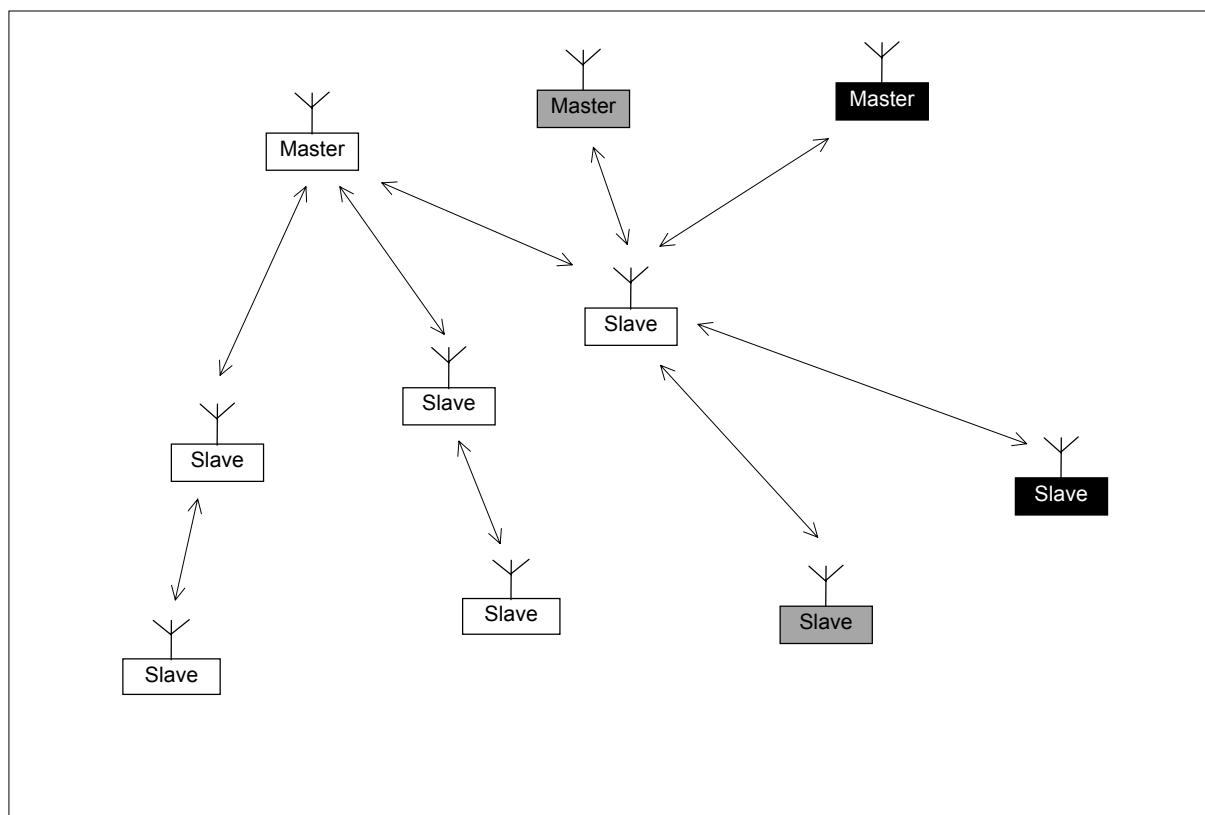
9 Installation

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 121 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 121* 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 121* 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 with 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:

Output voltage:	12.5VDC nom. (11.5-13.5)
Output 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:
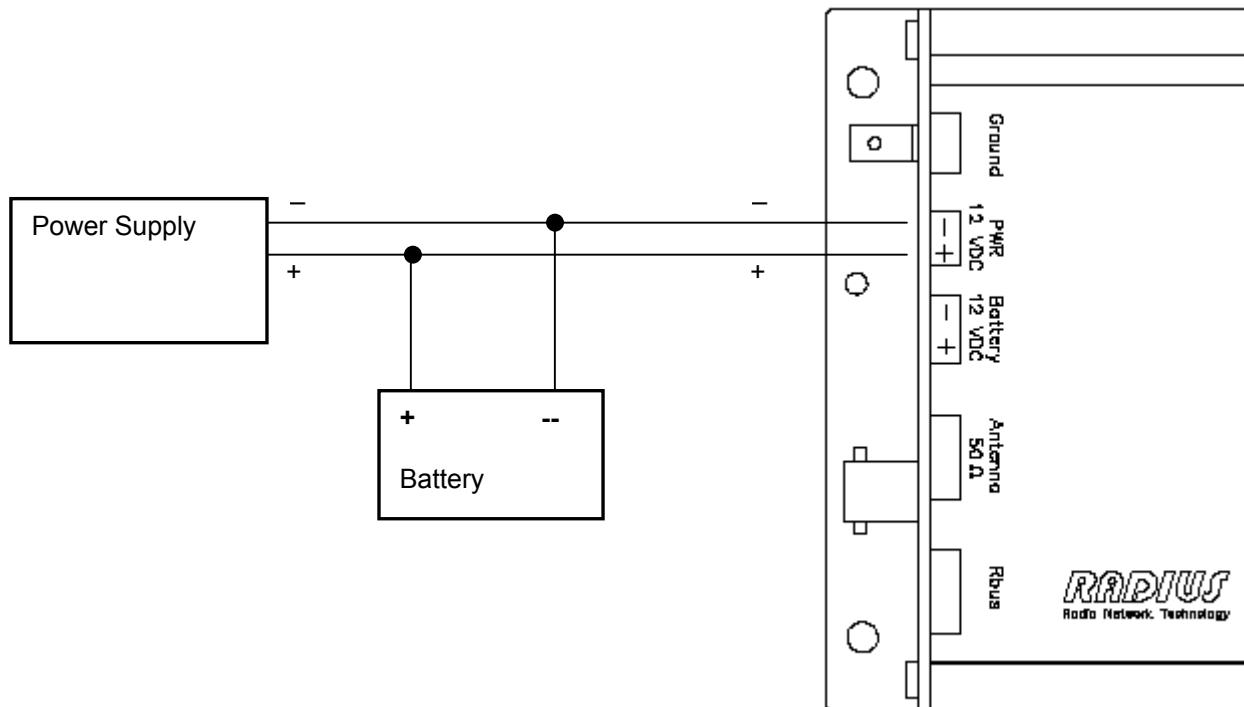
Note! The Battery Input shall only be used for non-rechargeable batteries.

9.4 Serial Interface

The PDR 121 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 12.6 for configuration.

9.4.1 PDR 121 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 PDR 121 can be configured to activate the DCD before and after transmission of the serial data. Pre- and Post DCD. Se Figure 7 and Figure 8. See also configuration chapter 12.6.
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 PDR 121.
5	-	GND – Signal Ground
6	Out	DSR – Data Set Ready Always active/high when in normal operation mode. DSR is deactivated/low when PDR 121 is in configuration mode. I.e. not ready to receive data on the serial port.
7	In	RTS – Request To Send Not used by the PDR 121. The PDR is always instantly ready to receive data when the CTS are high.
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. See Figure 6, Figure 7 and Figure 8. **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 PDR 121. (Used by DCE telephone modem equipment. Indicates ring signal on a telephone line).

Table 1. Serial data interface connector pinouts.

It is not always 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. See chapter 9.4.1 below.

Note! The PDR 121 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. However, It is most often possible to use a "three wire connection" like cable type 2.

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 – DCD

Cable Type 1

DTE DB9F		PDR (DCE) DB9M
DCD 1	←	1 DCD
RD 2	←	2 RD
TD 3	→	3 TD
DTR 4	→	4 DTR
DSR 6	←	6 DSR
RTS 7	→	7 RTS
CTS 8	←	8 CTS
RI 9	←	9 RI
GND 5	—	5 GND

Cable Type 2

DTE DB9F		PDR (DCE) DB9M
DCD 1		1 DCD
RD 2	←	2 RD
TD 3	→	3 TD
DTR 4		4 DTR
DSR 6		6 DSR
RTS 7		7 RTS
CTS 8		8 CTS
RI 9		9 RI
GND 5	—	5 GND

Cable Type 3

DTE DB9F		PDR (DCE) DB9M
DCD 1		1 DCD
RD 2	←	2 RD
TD 3	→	3 TD
DTR 4		4 DTR
DSR 6		6 DSR
RTS 7		7 RTS
CTS 8		8 CTS
RI 9		9 RI
GND 5	—	5 GND

Cable Type 4

DTE DB25F		PDR (DCE) DB9M
DCD 8	←	1 DCD
RD 3	←	2 RD
TD 2	→	3 TD
DTR 20	→	4 DTR
DSR 6	←	6 DSR
RTS 4	→	7 RTS
CTS 5	←	8 CTS
RI 22	←	9 RI
GND 7	—	5 GND

Cable Type 5

DTE DB25F		PDR (DCE) DB25M
DCD 8		1 DCD
RD 3	←	2 RD
TD 2	→	3 TD
DTR 20		4 DTR
DSR 6		6 DSR
RTS 4		7 RTS
CTS 5		8 CTS
RI 22		9 RI
GND 7	—	5 GND

Cable Type 6

DTE DB25F		PDR (DCE) DB9M
DCD 8		1 DCD
RD 3	←	2 RD
TD 2	→	3 TD
DTR 20		4 DTR
DSR 6		6 DSR
RTS 4		7 RTS
CTS 5		8 CTS
RI 22		9 RI
GND 7	—	5 GND

Figure 4. DTE-DCE serial cable configurations

9.4.2.2 DCE – DCE

Cable Type 7

DCE   PDR (DCE)
DB9M   DB9M

DCD 1 ⊃ ——←—— ⊏ 1 DCD
RD 2 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 3 ⊃ ————╱╲———— ⊏ 3 TD
DTR 4 ⊃ ——╲╱—— ⊏ 4 DTR
DSR 6 ⊃ —→—╱╲—←— ⊏ 6 DSR
RTS 7 ⊃ ——╲╱—— ⊏ 7 RTS
CTS 8 ⊃ —→—╱╲—←— ⊏ 8 CTS
RI 9 ⊃ ⊏ 9 RI
GND 5 ⊃ ——←—— ⊏ 5 GND

Cable Type 8

DCE   PDR (DCE)
DB9M   DB9M

DCD 1 ⊃ ⊏ 1 DCD
RD 2 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 3 ⊃ ————╱╲———— ⊏ 3 TD
DTR 4 ⊃ ⊏ 4 DTR
DSR 6 ⊃ ⊏ 6 DSR
RTS 7 ⊃ ⊏ 7 RTS
CTS 8 ⊃ ⊏ 8 CTS
RI 9 ⊃ ⊏ 9 RI
GND 5 ⊃ ———— ⊏ 5 GND

Cable Type 9

DCE   PDR (DCE)
DB9M   DB9M

DCD 1 ⊃ ⊏ 1 DCD
RD 2 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 3 ⊃ ————╱╲———— ⊏ 3 TD
DTR 4 ⊃┐ ⊏ 4 DTR
DSR 6 ⊃┘ ⊏ 6 DSR
RTS 7 ⊃┐ ⊏ 7 RTS
CTS 8 ⊃┘ ⊏ 8 CTS
RI 9 ⊃ ⊏ 9 RI
GND 5 ⊃ ———— ⊏ 5 GND

Cable Type 10

DCE   PDR (DCE)
DB25   DB9M

DCD 8 ⊃ ——←—— ⊏ 1 DCD
RD 3 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 2 ⊃ ————╱╲———— ⊏ 3 TD
DTR 20 ⊃ ——╲╱—— ⊏ 4 DTR
DSR 6 ⊃ —→—╱╲—←— ⊏ 6 DSR
RTS 4 ⊃ ——╲╱—— ⊏ 7 RTS
CTS 5 ⊃ —→—╱╲—←— ⊏ 8 CTS
RI 22 ⊃ ———— ⊏ 9 RI
GND 7 ⊃ ——←—— ⊏ 5 GND

Cable Type 11

DCE   PDR (DCE)
DB25M   DB9M

DCD 8 ⊃ ⊏ 1 DCD
RD 3 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 2 ⊃ ————╱╲———— ⊏ 3 TD
DTR 20 ⊃ ⊏ 4 DTR
DSR 6 ⊃ ⊏ 6 DSR
RTS 4 ⊃ ⊏ 7 RTS
CTS 5 ⊃ ⊏ 8 CTS
RI 22 ⊃ ⊏ 9 RI
GND 7 ⊃ ———— ⊏ 5 GND

Cable Type 12

DCE   PDR (DCE)
DB25M   DB9M

DCD 8 ⊃ ⊏ 1 DCD
RD 3 ⊃ —→—╲╱—←— ⊏ 2 RD
TD 2 ⊃ ————╱╲———— ⊏ 3 TD
DTR 20 ⊃┐ ⊏ 4 DTR
DSR 6 ⊃┘ ⊏ 6 DSR
RTS 4 ⊃┐ ⊏ 7 RTS
CTS 5 ⊃┘ ⊏ 8 CTS
RI 22 ⊃ ⊏ 9 RI
GND 7 ⊃ ———— ⊏ 5 GND

Figure 5. DCE-DCE serial cable configurations

9.4.2.3 CTS Operation during Radio Tx

RS232 Rx   :   PDR121 receives a serial message from the control system

Radio Tx   :   PDR121 transmits the message on the radio

CTS   :   CTS becomes low while the message is transmitted on the radio
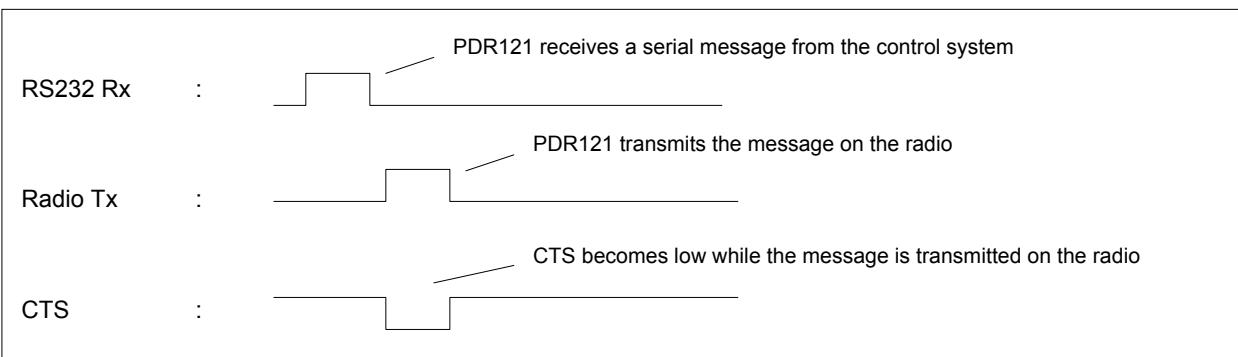
Figure 6. CTS operation when transmitting a received serial message on the radio.

9.4.2.4 CTS And DCD Operation during Radio Rx

Radio Rx   :   PDR121 receives a radio message

RS232 Tx   :   PDR121 transmits the message across the serial interface to the control system

CTS   :   CTS is low during detection of the message, until it has been transmitted across the serial interface

DCD   :   DCD signal is high during the transmission of the message to the control system on the serial interface
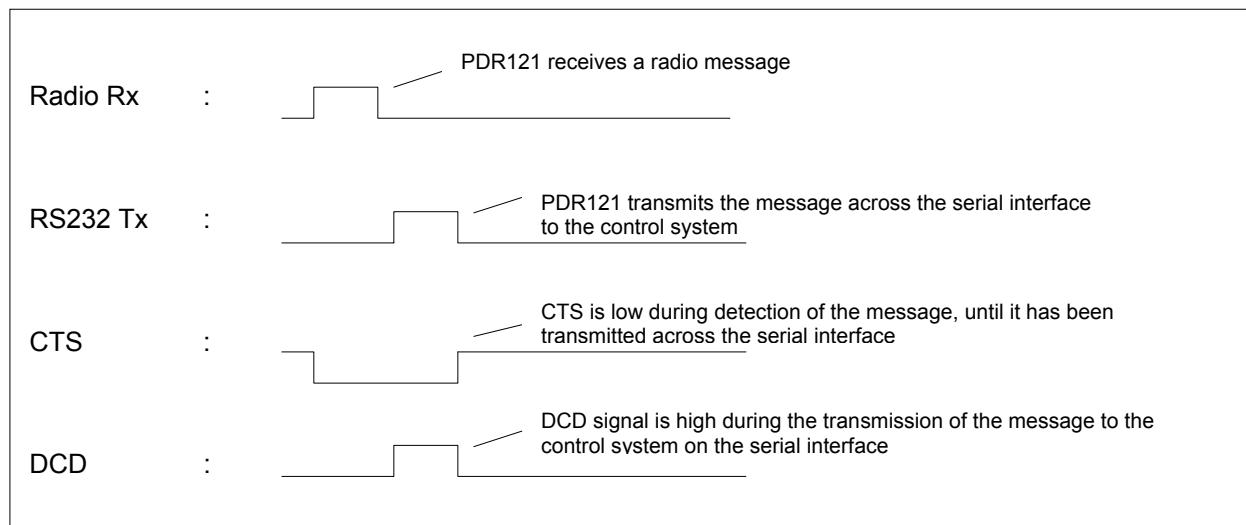
Figure 7. CTS and DCD operation when receiving a radio message.

9.4.2.5 Pre- and Post DCD

PDR121 receives a radio message

Radio Rx   :

PDR121 transmits the message on the serial interface after configured Pre DCD time

RS232 Tx   :

DCD is high during the Pre DCD time, the serial transmission time and configured Post DCD time

DCD   :

Pre DCD   Post DCD

CTS   :

CTS is low from when the message is detected on the radio until the Post DCD time is ended

Figure 8. DCD and CTS operation when using Pre DCD and Post DCD time

9.4.3 EIA RS323 Conversion Table

EIA RS232	ITU-T (CCITT) V24	Description
TD (TxD)	103	Transmitted Data from DTE
RD (RxD)	104	Received Data to DTE
RTS	105	Request To Send from DTE
CTS	106	Clear To Send to DTE
DSR	107	Data Set Ready to DTE
DTR	108/2	Data Terminal Ready from DTE
DCD	109	Data Carrier Detect to DTE
RI	125	Ring Indication to DTE
GND		Signal Ground

9.5 Cabinet Mounting

9.5.1 PDR 121 mounted in cabinet

If the Packet Data Radio 121 is mounted in a cabinet, this is built up as shown below:
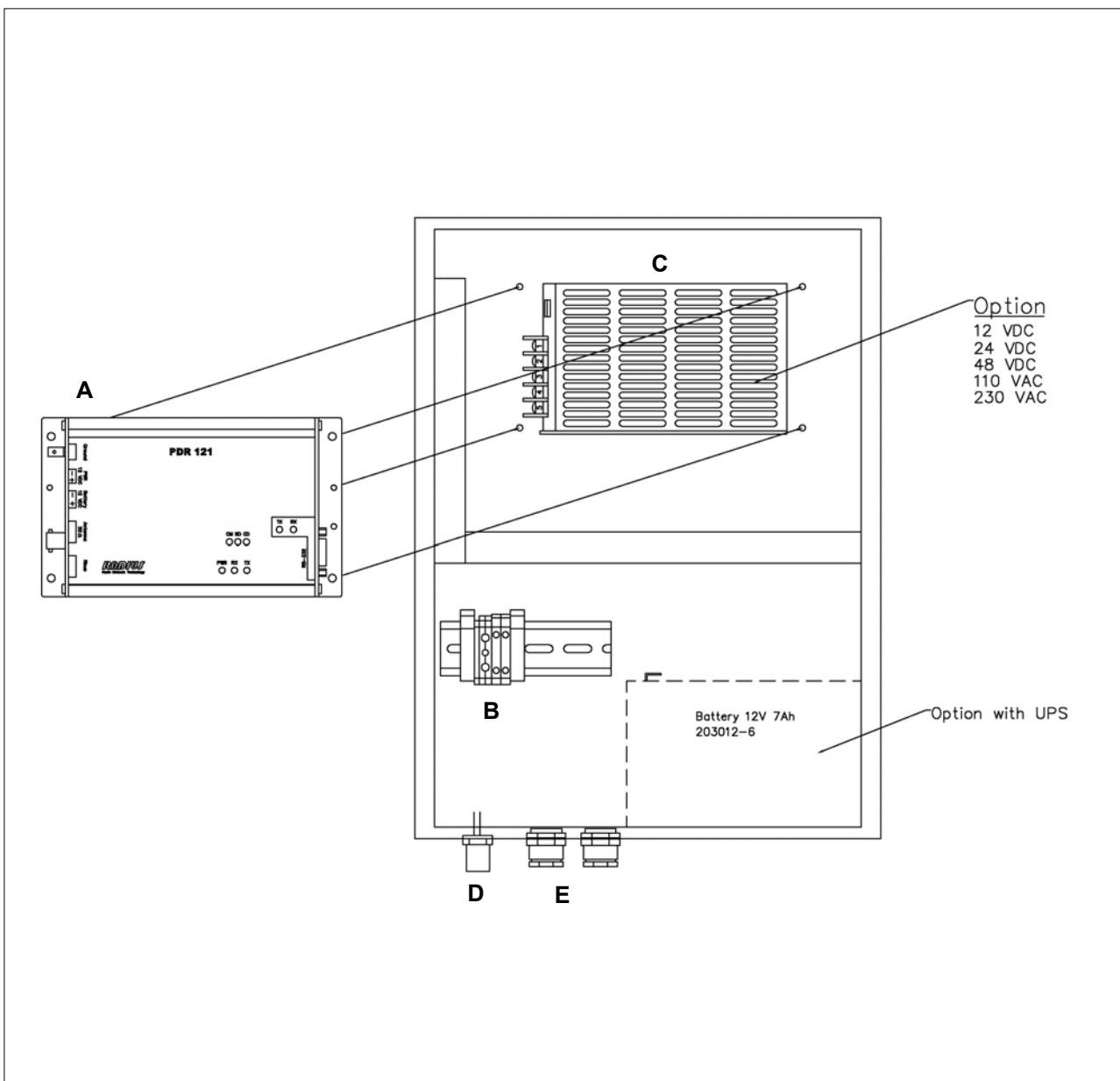
Object	Name	Description
A	Packet Data Radio	Data radio.
B	Connection block	For connection of mains. Phase, neutral or earth.
C	Power supply	Converts mains to 12VDC
D	Coaxial connector N-jack.	For connection of the antenna cable
E	Cable gland (duct)	For leading cables through the cabinet

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

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 PDR 121.

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 an isotropic antenna. This can be compared to using a pair of binoculars. You will see 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.
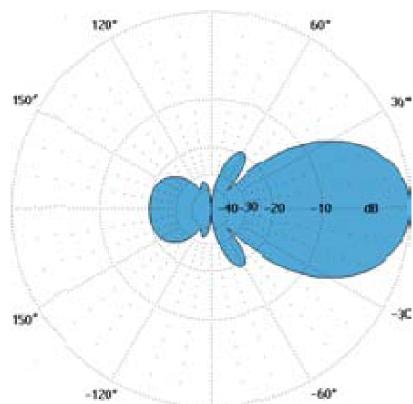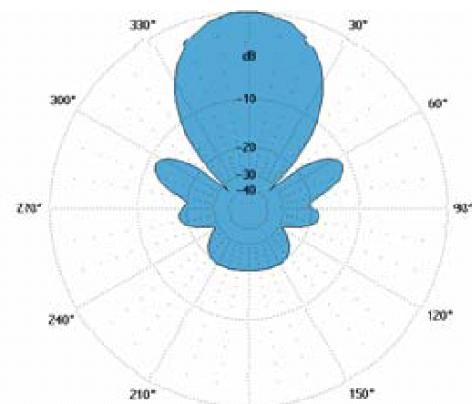
11.1.2.2 Omni-Directional Antenna

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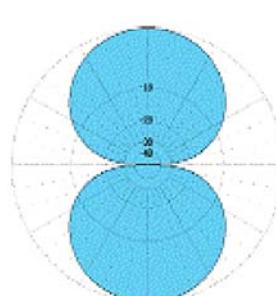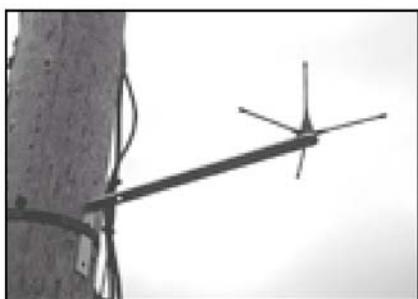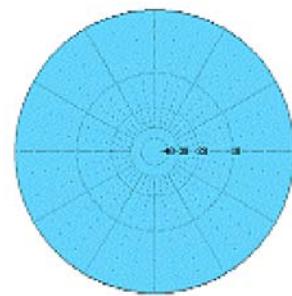
E-plane   H-plane

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.
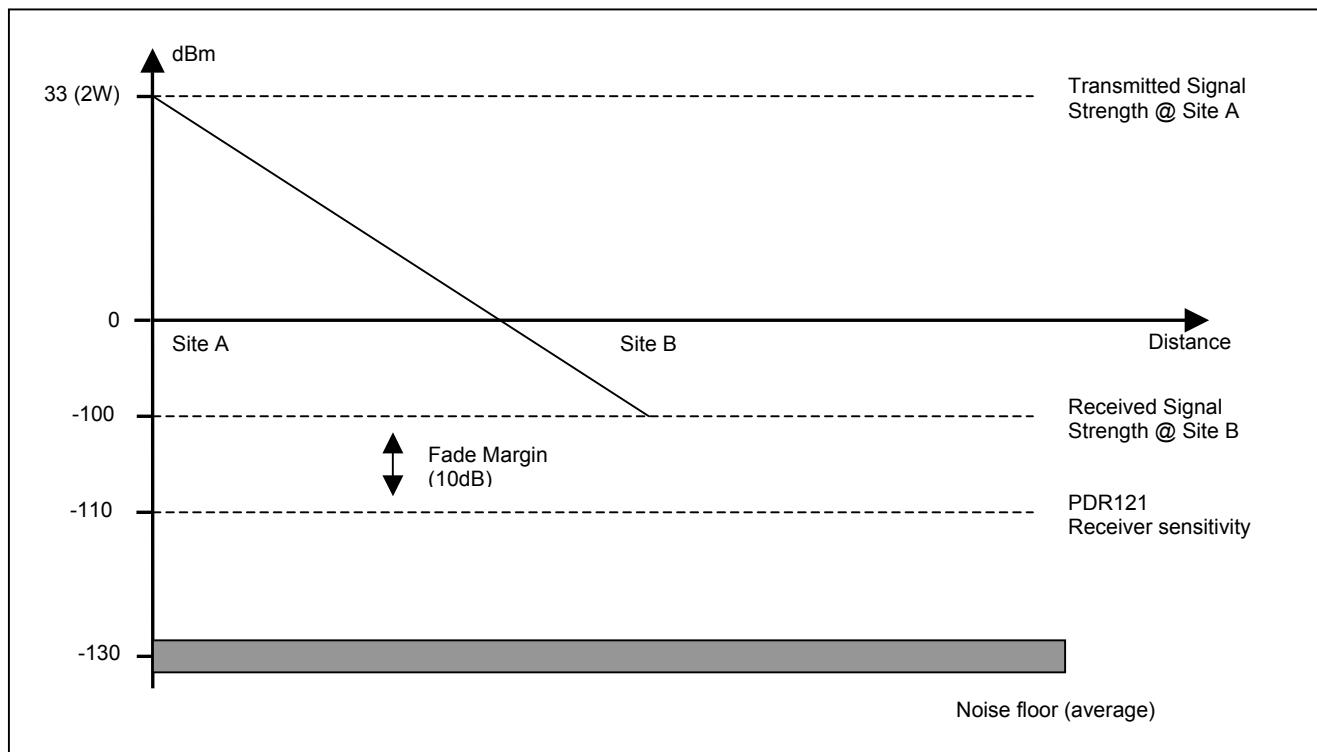
Figure 10. Fade Margin

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 cannot 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 desktop propagation study using a 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 kilometres

1 feet = 0.305 meter

Metric system users can use the formula:

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

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 a 142 MHz RF signal will be attenuated 143.6 dB over a distance of 12.5 miles (20 kilometres).

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   – CI ->

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 – CI ->

A =   Srx   + Ptx   + Gtx   + Grx   – CI   – 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 ($\lambda/4\pi$***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

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 the Tx 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 PDR 121 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 PDR 121 configuration menus.

1. Ensure that the PDR 121 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 PDR 121 configuration menus.

Note! After configuration, "Exit Configuration" must be chosen or else the PDR 121 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 - PDR121
Copyright RADIUS Sweden AB
Software: PDR121S v1.0 Build Sep 15 2004
ArtNo:303062-4 SwNo:50 HwNo:18


Executing

Press C to enter configuration mode



```

Note! If the PDR 121 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 - PDR121
Copyright RADIUS Sweden AB
Software: PDR121S v1.0 Build Sep 15 2004
ArtNo:303062-4 SwNo:50 HwNo:18

1. Network
2. Serial
3. Radio
4. Advanced
5. List Configuration

E. Exit Configuration Mode
```

See 12.5, page 48.

```
Network

1. System ID      : 01
2. Radio ID       : 01
3. RTU 01..20
4. RTU 21..40
5. RTU 41..60
6. RTU 61..80
7. RTU 81..99
8. Repeat Alternative Systems
9. View Network
A. Clear Network
```

See 12.6, page 50.

```
Serial

1. Protocol                : DNP3
2. Bitrate                 : 9600 bps
3. Parity                  : No
4. Inter Character Timeout : 990 ms
5. Pre DCD                 : 40 ms
6. Post DCD                : 0 ms
```

See 12.7, page 51.

```
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

Rx Frequency               : 465.000000 MHz
Tx Frequency               : 465.000000 MHz
```

See 12.8, page 52.

```
Advanced

1. Detected Radio Type       : UHF 450..470 MHz
2. Rx Frequency              : 465000000 Hz
3. Tx Frequency              : 465000000 Hz
4. Split Tx Uplink           : OFF
5. Split Tx Uplink Frequency : 000000000 Hz
6. Split Tx Uplink Id        : 01
7. Radio Bitrate             : 9600 bps
8. Tx Power Level            : 27 dBm (0.53 W)
9. Non-Intrusive Diagnostics : OFF
A. Realtime RSSI
B. Extended Communication Test
C. System Frequency Change
D. Remote Tx Power Level Change
E. Radio VCO Lock Test
F. Terminal Bitrate
```

See 12.9, page
54.

```
No.  RTU Adr  Radio Id  R1  R2  R3  R4  R5  R6
01.  00001    01        --  --  --  --  --  --
02.  00002    02        01  --  --  --  --  --

System Id                      : 01
Radio Id                       : 99
Protocol                       : DNP3
Serial                         : 9600 8N1
Inter Character Timeout        : 250 ms
Pre DCD                        : 0 ms
Post DCD                       : 0 ms
Collision Avoidance Delay      : OFF
Collision Avoidance Delay Min  : 0 ms
Collision Avoidance Delay Max  : 0 ms
Rx Frequency                   : 0.000000 MHz
Tx Frequency                   : 0.000000 MHz
Split Tx Uplink                : OFF
Split Tx Uplink Frequency      : 0.000000 MHz
Split Tx Uplink Id             : --
Radio Bitrate                  : 9600 bps
Tx Power Level                 : 20 dBm (0.10 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 - PDR121
Copyright RADIUS Sweden AB
Software: PDR121S v1.0 Build Sep 15 2004
ArtNo:303062-4 SwNo:50 HwNo:18

1. Network
2. Serial
3. Radio
4. Advanced
5. 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 Network

The Network menu contains all routing parameters each radio needs to communicate to other radios in the network.

```
Network

1. System ID     : 01
2. Radio ID      : 01
3. RTU 01..20
4. RTU 21..40
5. RTU 41..60
6. RTU 61..80
7. RTU 81..99
8. Repeat Alternative Systems
9. View Network
A. Clear Network
```

12.5.1 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..99. (Entering 00 will clear the System ID). See also chapter 12.5.4, Repeat Alternative Systems.

12.5.2 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..99.Thus, one PDR radio network can contain 99 radio units. (Entering 00 will clear the Radio ID).

12.5.3 RTU 01..20 – RTU 81..99

The RTU menus contain the message routing information.

Note! The RTU Id configuration differs depending on which protocol is used.

Configuration of the Master radio network menu is similar for all protocols. The destination RTU address is entered. The difference between protocols regards configuration of the slave radios. This difference is because the method of addressing the RTU response message differs between protocols..

When configuring the Network menu on a slave radio:

DNP3 Protocol: The control system (SCADA) address is entered as the RTU Id.

IEC870/RP570 Protocol: The connected RTU address is entered as the RTU Id.

COMLI: Address 00000 (zero) is always entered as RTU Id.

Also see the network configuration examples in chapter 12.10.

DNP3 messages contain both source and destination addresses. IEC870 and RP570 messages contain only the RTU address. Comli messages always contain the address 0 (zero) when transmitted to the control system.

When the PDR 121 master receives a message on the serial port, it checks if the protocol address is configured in the RTU Id list. If the address is listed, the message will be transmitted to the radio (Id) tied to the RTU Id address in the list. The example below tells the radio to transmit messages addressed to RTU 00001 to radio 01. Messages to RTU 00002 shall be transmitted to radio 02 via radio 01. (See also the network configuration example in chapter 12.10).

```
No.   RTU Adr   Radio Id  R1   R2   R3   R4   R5   R6
01.   00001     01        --   --   --   --   --   --
02.   00002     02        01   --   --   --   --   --
03.   -----     --        --   --   --   --   --   --
04.   -----     --        --   --   --   --   --   --
05.   -----     --        --   --   --   --   --   --
06.   -----     --        --   --   --   --   --   --
07.   -----     --        --   --   --   --   --   --
08.   -----     --        --   --   --   --   --   --
09.   -----     --        --   --   --   --   --   --
10.   -----     --        --   --   --   --   --   --
11.   -----     --        --   --   --   --   --   --
12.   -----     --        --   --   --   --   --   --
13.   -----     --        --   --   --   --   --   --
14.   -----     --        --   --   --   --   --   --
15.   -----     --        --   --   --   --   --   --
16.   -----     --        --   --   --   --   --   --
17.   -----     --        --   --   --   --   --   --
18.   -----     --        --   --   --   --   --   --
19.   -----     --        --   --   --   --   --   --
20.   -----     --        --   --   --   --   --   --

Select No : --
```

RTU ID   : The protocol address of the remote/local RTU. (See note above).
Radio ID : The Radio Id of the radio connected to the remote RTU.
R1..R6   : The Radio Id of repeaters to be used to reach the radio connected to the remote RTU.

The master radio connected to the central control (SCADA), shall have all remote (slave) RTU addresses configured in the Network RTU list along with the remote radio id's and eventual repeater id's.

12.5.3.1 Multiple RTU's

Several RTU's can be connected to one PDR radio via a RS232/RS485 interface. This is achieved by configuring the RTU addresses to the same radio id in the Network RTU list.

12.5.3.2 Peer To Peer

If a remote RTU (1) shall communicate to another remote RTU (2), the address of RTU (2), and the radio id's, shall be configured in the Network RTU list of RTU (1).

12.5.4 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.

12.5.5 View Network

View Network displays all configured RTU's and the radio paths.

12.5.6 Clear Network

Clear Network deletes all routing configuration in the Network menu. If Clear Network is selected, a confirmation is required before the network information will be cleared.

12.6 Serial

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

```
Serial

1. Protocol               : DNP3
2. Bitrate                : 9600 bps
3. Parity                 : No
4. Max Space Between Chr:s : 990 ms
5. Pre DCD                : 0 ms
6. Post DCD               : 0 ms
```

12.6.1 Protocol

This feature is for the selection of the serial interface (RTU/SCADA) protocol. Available protocols are IEC870, RP570, DNP3 or COMLI.

12.6.2 Bitrate

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

12.6.3 Parity

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

12.6.4 Inter Character Timeout

This feature is for the selection of the maximal space, in time (ms), between characters in a serial telegram to be accepted by the PDR 121. Entering '00' inhibits the function and the PDR 121 accepts an infinite amount of time between characters in an incoming telegram. Note: Entering "00" is not recommended for most communication applications.

If there is a space exceeding the configured Inter Character Timeout, the PDR will discard the message. The connected RTU has then to re-transmit a complete message.

12.6.5 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.

12.6.6 Post DCD

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

12.7 Radio

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

```
Radio

1. Collision Avoidance Delay     : ON
2. Collision Avoidance Delay Min : 0 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
```

12.7.1 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.

12.7.2 Collision Avoidance Delay Min

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

12.7.3 Collision Avoidance Delay Max

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

12.7.4 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 14.1 for a more in depth description.

12.7.5 Communication Test

The Communication Test is used to check the communication path between two radios in the network. See chapter 14.2 for a more in depth description.

12.7.6 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. See chapter 14.3 for a more in depth description.

12.7.7 Receiver Test

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

12.7.8 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.

12.8 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 450..470 MHz
2. Rx Frequency             : 465000000 Hz
3. Tx Frequency             : 465000000 Hz
4. Split Tx Uplink          : OFF
5. Split Tx Uplink Frequency : 460000000 Hz
6. Split Tx Uplink Id       : 01
7. Radio Bitrate            : 9600 bps
8. Tx Power Level           : 27 dBm (0.53 W)
9. Non-Intrusive Diagnostics : OFF
A. Realtime RSSI
B. Extended Communication Test
C. System Frequency Change
D. Remote Tx Power Level Change
E. Radio VCO Lock Test
F. Terminal Bitrate
```

12.8.1 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.

12.8.2 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...
```

12.8.3 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.

12.8.4 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. See chapter 8.9 for an example network. If enabled the configured split Tx uplink frequency is used when transmitting to radio id indicated by split Tx uplink id, all other transmissions is done on the normal Tx frequency.

12.8.5 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.

12.8.6 Split Tx Uplink Id

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

12.8.7 Radio Link Speed

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

12.8.8 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)
```

12.8.9 Non-Intrusive Diagnostics

When this feature is activated the radio will receive diagnostic parameters from all radio units in the network and write them out on the Rbus. (57600 N81). In order to be able to read the diagnostics the RADIUS Windows based network tool is needed. The diagnostic parameters are RSSI, temperature, transmitter power and supply voltage.

12.8.10 Realtime RSSI

Shows the Recieved Signal Strength in realtime. This feature is usable when adjusting the antenna direction. This is easily done by chosing the radio ID of a PDR 121 to which the communication is intended. The chosen radio will then start a continous bit stream during 1 minute. The radio will send an request to the chosen radio ID and will then automatically show the RSSI in realtime.

12.8.11 Extended Communication Test

The Extended Communication Test functions in the same way as the "ordinary" Communication Test, with the soul difference that the Extended Test has to be aborted by the user. The number of *Failed* are shown within brackets.
NOTICE! Make sure that no other communication is occuring in the network during the test, since this may influence the result of the Extended Communication Test.

12.8.12 System Frequency Change

This feature changes the radio network frequency remotely to all radio units on the network. See chapter 8.4 for detailed description.

12.8.12.1 Split Uplink Frequency

The System Frequency Change feature is designed to support split uplink frequency. If separate Rx / Tx frequencies are 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.

12.8.13 Remote Tx Power Level Change

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

12.8.14 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
```

12.8.15 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
```

12.9 List Configuration

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

```
No.   RTU Adr  Radio Id  R1  R2  R3  R4  R5  R6
01.   00001    01        --  --  --  --  --  --
02.   00002    02        01  --  --  --  --  --


System Id                     : 01
Radio Id                      : 99
Protocol                      : DNP3
Serial                        : 9600 8N1
Inter Character Timeout       : 250 ms
Pre DCD                       : 0 ms
Post DCD                      : 0 ms
Collision Avoidance Delay     : OFF
Collision Avoidance Delay Min : 0 ms
Collision Avoidance Delay Max : 0 ms
Rx Frequency                  : 0.000000 MHz
Tx Frequency                  : 0.000000 MHz
Split Tx Uplink               : OFF
Split Tx Uplink Frequency     : 0.000000 MHz
Split Tx Uplink Id            : --
Radio Bitrate                 : 9600 bps
Tx Power Level                : 20 dBm (0.10 W)
Non-Intrusive Diagnostics     : OFF


Press any key to continue...
```

12.10 Default Configuration

The example below shows the default settings of the PDR 121. Those settings will occur if the clear configuration function is activated.

```
System Id                     : 00
Radio Id                      : 00
Protocol                      : DNP3
Serial Interface              : 9600 8N1
Max Space Between Chr:s       : 50 ms
Pre DCD                       : 0 ms
Post DCD                      : 0 ms
Collision Avoidance Delay     : OFF
Collision Avoidance Delay Min : 0 ms
Collision Avoidance Delay Max : 0 ms
Rx Frequency                  : 000.000000 MHz
Tx Frequency                  : 000.000000 MHz
Use Split Tx Uplink           : No
Split Tx Uplink Frequency     : 000.000000 MHz
Split Tx Uplink Id            : 00
Radio Link Speed              : 9600 bps
Tx Power Level                : 20 dBm (0.10 W)
Non-Intrusive Diagnostics     : OFF
```

13 Configuration Examples

Note! The differences in radio network menu configuration between the protocols is due to different RTU address content. The DNP3 protocol messages contain both source and destination adresses, (control system and RTU adresses). The IEC870 and RP570 protocol contain the RTU address only. Even on reply to the control system. The COMLI protocol uses the adress zero for messages from the RTU to the control system.

13.1 Network Layout

This network example is used for all configuration examples below.
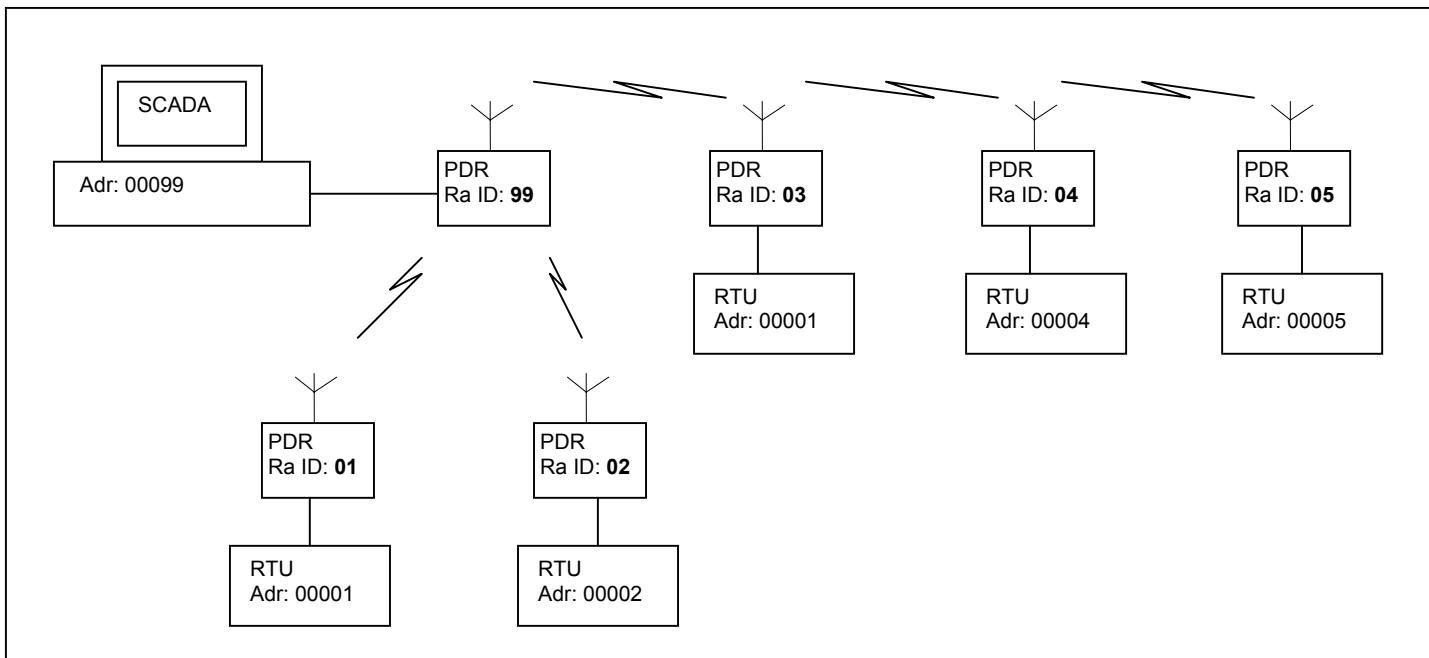
13.2 Network Menu Configurations – DNP3

The master radio network menu shall contain the remote DNP3 RTU addresses; the radio ID connected to the RTU and eventual repeater radio ID's.

The slave radio network menus shall contain **the DNP3 control system address**; the radio ID connected to the control system and eventual repeater radio ID's.

Radio 99 (Master):

```
      RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.   00001    01        --  --  --  --  --  --
02.   00002    02        --  --  --  --  --  --
03.   00003    03        --  --  --  --  --  --
04.   00004    04        03  --  --  --  --  --
05.   00005    05        03  04  --  --  --  --
06.   -----    --        --  --  --  --  --  --
...
```

Radio 01, 02, 03:

```
      RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.   00099    99        --  --  --  --  --  --
02.   -----    --        --  --  --  --  --  --
...
```

Radio 04:

```
      RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.   00099    99        03  --  --  --  --  --
02.   -----    --        --  --  --  --  --  --
...
```

Radio 05:

```
      RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.   00099    99        04  03  --  --  --  --
02.   -----    --        --  --  --  --  --  --
...
```

13.3 Network Menu Configurations – IEC870 / RP570

The master radio network menu shall contain the remote IEC870 / RP570 RTU addresses; the radio ID connected to the RTU and eventual repeater radio ID's.

The slave radio network menus shall contain **the connected IEC870 / RP570 RTU address**, the radio ID connected to the control system and eventual repeater radio ID's.

Radio 99 (Master):

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00001    01        --  --  --  --  --  --
02.  00002    02        --  --  --  --  --  --
03.  00003    03        --  --  --  --  --  --
04.  00004    04        03  --  --  --  --  --
05.  00005    05        03  04  --  --  --  --
06.  -----    --        --  --  --  --  --  --
...
```

Radio 01:

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00001    99        --  --  --  --  --  --
02.  -----    --        --  --  --  --  --  --
...
```

Radio 02:

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00002    99        --  --  --  --  --  --
02.  -----    --        --  --  --  --  --  --
...
```

Radio 03:

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00003    99        --  --  --  --  --  --
02.  -----    --        --  --  --  --  --  --
...
```

Radio 04:

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00004    99        03  --  --  --  --  --
02.  -----    --        --  --  --  --  --  --
...
```

Radio 05:

```
     RTU Id   Radio Id  R1  R2  R3  R4  R5  R6
01.  00005    99        04  03  --  --  --  --
02.  -----    --        --  --  --  --  --  --
...
```

13.4 Network Menu Configurations – COMLI

The master radio network menu shall contain the remote COMLI RTU addresses; the radio ID connected to the RTU and eventual repeater radio ID's.

The slave radio network menus shall contain **the address zero,** which is the COMLI protocol master address; the radio ID connected to the control system and eventual repeater radio ID's.

Radio 99 (Master):

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00001     01        --  --  --  --  --  --
02.   00002     02        --  --  --  --  --  --
03.   00003     03        --  --  --  --  --  --
04.   00004     04        03  --  --  --  --  --
05.   00005     05        03  04  --  --  --  --
06.   -----     --        --  --  --  --  --  --
...
```

Radio 01:

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00000     99        --  --  --  --  --  --
02.   -----     --        --  --  --  --  --  --
...
```

Radio 02:

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00000     99        --  --  --  --  --  --
02.   -----     --        --  --  --  --  --  --
...
```

Radio 03:

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00000     99        --  --  --  --  --  --
02.   -----     --        --  --  --  --  --  --
...
```

Radio 04:

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00000     99        03  --  --  --  --  --
02.   -----     --        --  --  --  --  --  --
```

Radio 05:

```
      RTU Id    Radio Id  R1  R2  R3  R4  R5  R6
01.   00000     99        04  03  --  --  --  --
02.   -----     --        --  --  --  --  --  --
...
```

14 Radio Test Functions

14.1 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.
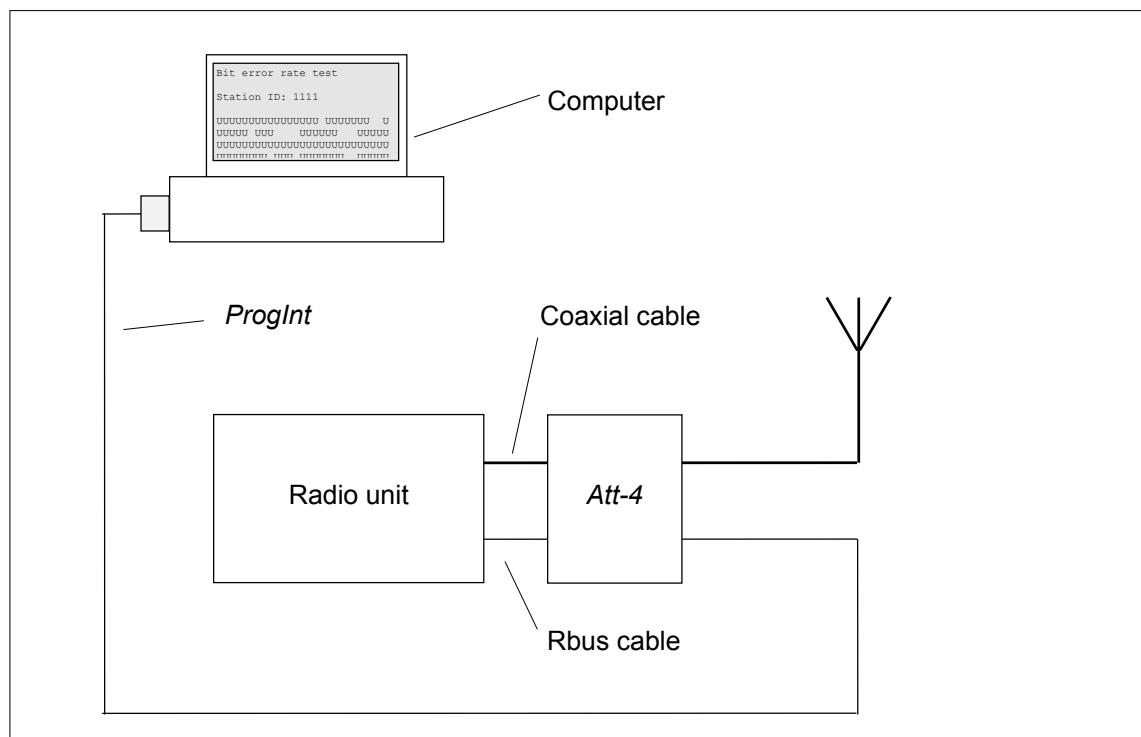
The transmission quality is evaluated by the result of the bit error rate test.
If no errors appear at the highest attenuation level, there is *at least* 30dB margin until bit errors appear. For secure data transmission, the attenuation levels 0, 1 and 2 should be without faults. On attenuation **level 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 'U' and an incorrectly received character is displayed as '.' (Dot). 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 11.
Bit error rate tests can be carried out between all radio types.

```
Bit error rate test

Attenuator detected

Radio ID: 02

UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUU..UUUU.UUUUUUU..UUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU...UUUUUUUUUUUUUUUUUUU
UUUUUUUU..UUUUUUUUU.UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU
UUUUUUUUUUUUUUUUUUUUU.UUUUUU.UUUUUUU.UUUUUUUUUUUUUUUU

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
```
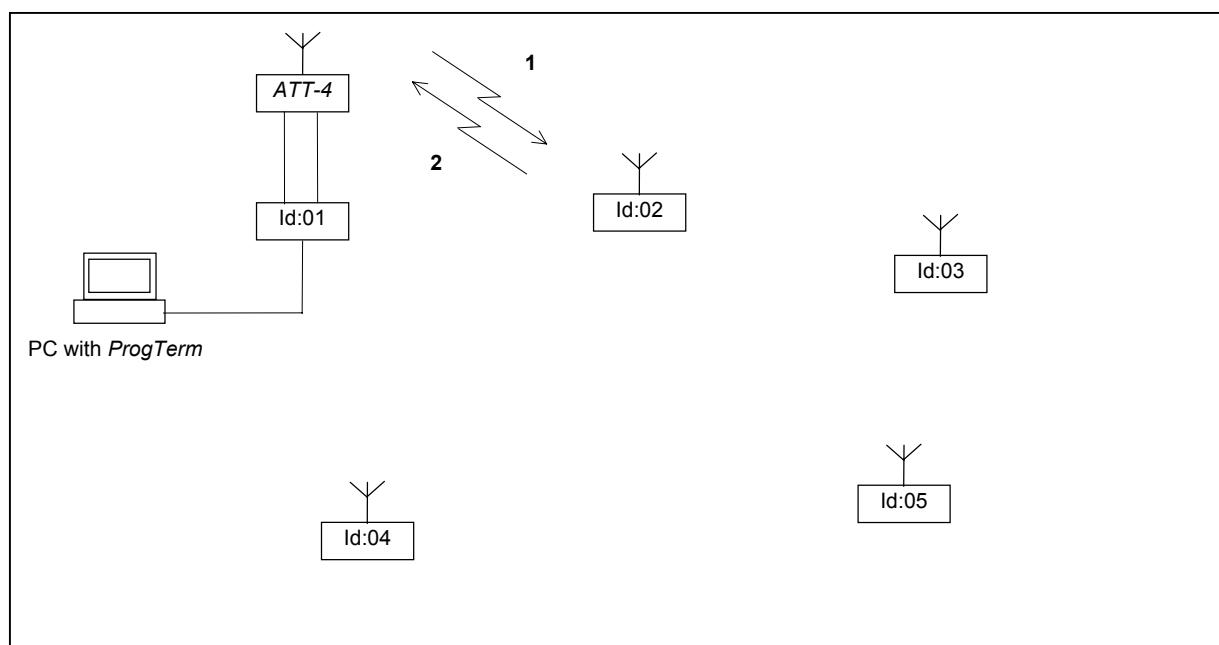
14.2 Communication Test

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.
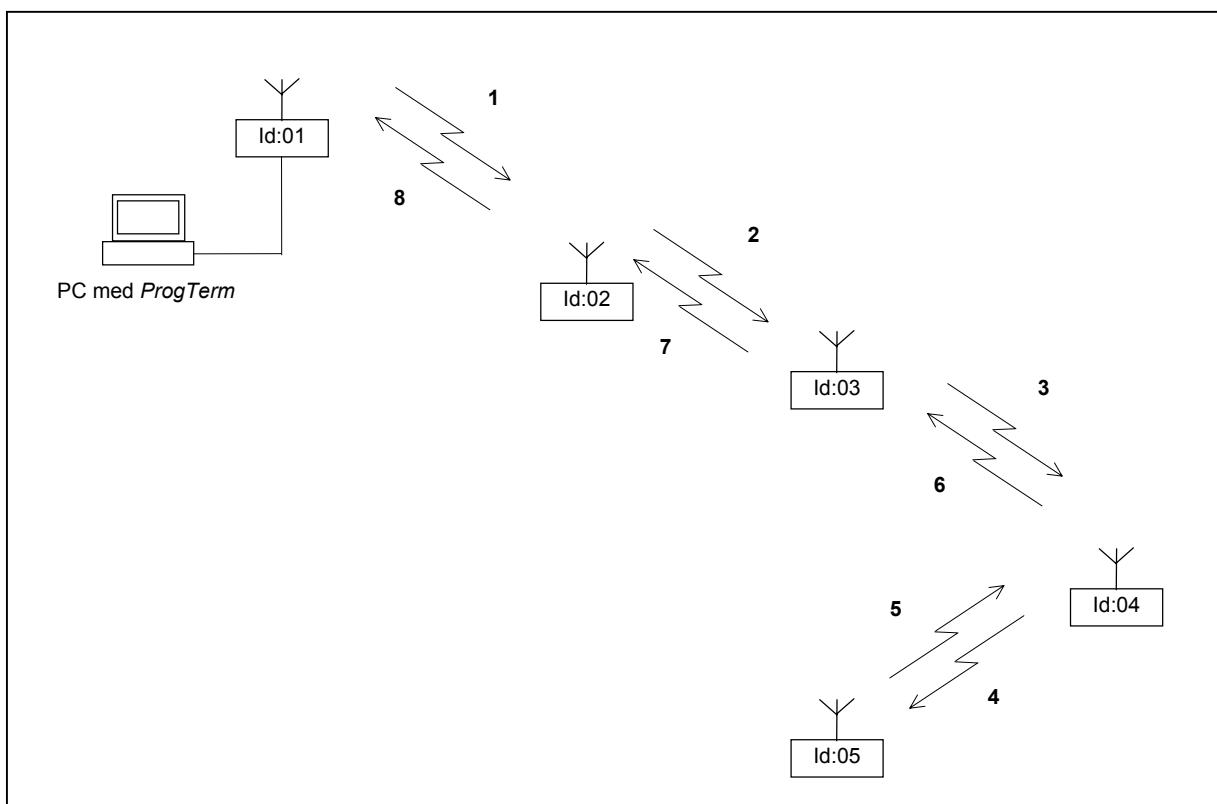

```
Communication Test

Radio Id : 05

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

Press any key to continue...
```

14.3 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

Downlink
Path        : 04 ---> 03 ---> 02 ---> 01
RSSI (dBm)  :    -80      -81      -78
TxPwr (dBm) :    +30      +20      +30

Uplink
Path        : 01 ---> 02 ---> 03 ---> 04
RSSI (dBm)  :    -76      -81      -80
TxPwr (dBm) :    +30      +30      +20

Press any key to continue...
```

The example above shows a Radio Link Test carried out from radio 04 to radio 01. The arrows indicate the direction of the radio message. The transmitter power at Radio 04 is +30dBm (1W) and the RSSI level at Radio 03 is –80dBm. The transmitter power at Radio 03 is +20 dBm and the RSSI level at Radio 02 is –81 dBm. Etc.

15 Trouble Shooting

15.1 Trouble Shooting the PDR

If installed according to [1] and 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 power LED flashing? This indicates that supply voltage is to low. Measure the voltage both in receiving and transmitting mode.
- 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 [1] installed nearby the radio?
- That the programming adapter is not connected during normal operation.
- 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 RSSI-value, compared to earlier? Try to adjust the antenna direction to achieve a better RSSI-value.
- 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. Check identities and repeater paths in both master and slave units.

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.

15.2 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	
US	+1 414 427 7010	support@radius-us.com	

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

16 Education and user feedback

16.1 Product education

It may be difficult in the beginning to become a user of a highly complex radio system, but please let us help you to speed-up the learning process. RADIUS offers various training covering our products and communication technology. We can arrange training classes if you want to let people in your organization to get a broad knowledge about your RADIUS system in general, or if you want your technicians to become "gurus" when it comes to crimping antenna connectors, trouble shooting and to create smart solutions with RADIUS system.

16.2 User feedback

Receiving user feedback is very important. Since many years Radius has a user group, NetMan Visionary Group, who discuss our products and how to improve them. We are always interested if you have suggestions on how we can improve anything, from features to shipping procedures.

AppendixA – PDR 121 Layout Drawing

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91

193

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RADIUS
Radio Network Technology

PDR 121

Rbus
Antenna 50Ω
Battery 12 VDC + −
PWR 12 VDC + −
Ground

PWR
RX
TX

CM SD CD

TX
RX

RS-232

Det.No.	Qty.	Name			Material	Mod.No. blank Dimension		Note
Designed by OlaRos	Drwn. by OlaRos	Checked by AndGra	Standard	Approved by		Scale 1:1	Replaces	ISO 2768–1
		PDR 121					Rev	Date 040528
							Drawing No. B013380 1	

RADIUS
Radio Network Technology

No Qty. Revision and/or message No. Date Issued Appr.by

References

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