Digital Transformation Group
Operational Technology

DESIGN STANDARD DS 42-02

SCADA Radio Network Design

VERSION 6
REVISION 1

FEBRUARY 2019

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of WA OSH Regulations 1996 (Division 12, Construction Industry – consultation on hazards and safety management) to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

https://www.legislation.wa.gov.au/legislation/statutes.nsf/law_s4665.html

Enquiries relating to the technical content of a Design Standard should be directed to the Principal SCADA Engineer, Operational Technology, Digital Transformation Group. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Manager, Operational Technology

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REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	**VER./ REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
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DESIGN STANDARD DS 42-02
SCADA Radio Network Design

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1 Preliminaries

1.1 Purpose

The purpose of this standard is to define radio design requirements for Water Corporation SCADA networks that will ensure reliable robust radio links are supplied and installed.

1.2 Scope

This standard shall apply to the design of UHF Narrowband, Cellular and Spread Spectrum SCADA radio installations operating in frequency band between 400 and 1000MHz and using one of the standard Water Corporation configurations as contained in Drawing Planset JT17 – see References.

All SCADA radio designs shall conform to these drawings, which shall constitute part of this Design Standard. These are referred to as the "JT17 Drawings".

UHF Narrowband radios shall include licensed 12.5, 25 and 50kHz narrowband radio modems operating in the 400 – 520 MHz band, nominally referred to as the 450 band throughout this Standard.

Cellular radio installations shall include data modems that connect to the Telstra Cellular 3G cellular network.

Spread Spectrum radios shall include unlicensed frequency hopping radios operating in the 915 – 928 class licence band.

For SCADA radio installation standards, refer to DS 42-03 SCADA Radio Equipment and Installation.

This standard complies with ACMA regulations that were applicable at the time of writing. The designer shall ensure compliance with future relevant changes to ACMA regulations.

1.3 Structure

The main body of this standard is divided into three separate portions. Sections 2, 3 and 4 cover UHF Narrowband, Cellular and Spread Spectrum radio design, respectively.

The appendices are likewise divided into separate portions. Appendix A addresses the risks associated with any radio design. Appendices B, C and D cover background information for UHF Narrowband, Cellular and Spread Spectrum radio design, respectively.

Appendix F summarises the changes from the previous version of this standard.

1.4 References

ETSI	EG 200 053 V1.5.1 (2004-06) Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio site engineering for radio equipment and systems
DS 42-03	Design Standard – SCADA Radio Equipment & Installation
PATHLOSS	Contract Telecommunication Engineering Pty Ltd, Canada
RALI FX16	ACMA Frequency Assignment Requirements for the Point to Multipoint Service in the 400 MHz and 900 Mhz Bands dated 14/02/2018

RALI FX17	ACMA Frequency Assignment Requirements for Narrowband Single Channel Two Frequency Point-to-Point Services in the 400 Mhz and 900 Mhz Bands dated 21/02/2018
WI 42-01	Work Instruction – UHF Radio Signal Level Measurements and Design Reports
WI 42-02	Work Instruction – NextG Measurements and Design Reports
Planset JT17	Standards Drawings – Radio Communications

1.5 Definitions

ACMA	Australian Communications and Media Authority
BER	Bit Error Rate
Corporation	Water Corporation (of Western Australia)
Design Fade Margin	The fade margin applicable to any RSL calculated during design.
Equivalent Isotropically Radiated Power (EIRP)	The equivalent power that would radiate from an isotropic radiator ie equally in all directions.
Fade Margin	Difference between the RSL at the receiver input and the Receiver Sensitivity.
Feasible Path	A radio path that is deemed to be feasible following a desktop map study, site survey; and/or estimation of the path loss using Pathloss software
Feeder Cable	A cable that connects the antenna to the radio system
Free Space Propagation	Free space propagation occurs when the transmitting and receiving antennas have a clear, unobstructed path between them.
Free Space Path Loss	Calculated radio signal path loss when Free Space Propagation conditions exist.
GDA94	Geocentric Datum of Australia 1994
JT17 Drawings	Planset JT17 Standards Drawings – Radio Communications
kbps	Kilo bits per second, as applicable to data rates
K Factor	The ratio of effective earth radius to actual earth radius. The effective earth radius enables radio path profiles to be drawn with a straight ray line.
Line of Sight Path	Where the site at the other end of an unobstructed path can be seen. Note: In most instances, a line of sight path cannot be determined from a map study; a site visit will be necessary.
LIPD	Low Interference Potential Device (LIPD) as applicable to an ACMA class licence.

Low Profile Antenna	A unity gain antenna that is mounted directly onto a building or cubicle.
MGA94	Map Grid of Australia 1994
MHz	Mega Hertz, as applicable to radio operating frequencies
Cellular Band	Downlink (base Tx): 870 – 890 MHz, nominally 880 MHz Uplink (base Rx): 825 – 845 MHz
Operational Fade Margin	The fade margin applicable to a working system RSL.
PP	Point-to-point
PMP	Point-to-multipoint
Propagation Measurement	Measurement of RSL on a radio path using radio test equipment.
Radio Base Station Repeater	A radio transmitter/receiver facility that communicates with many remote radios
Receiver Sensitivity	Minimum signal level at receiver input that will provide acceptable service. Equal to the specified 10^{-6} BER and 12 dB SINAD thresholds for digital radio modems and analogue radios, respectively.
Receive Signal Level (RSL)	Predited receive signal level at the radio receiver input
Remote Radio	In a PMP radio network, a radio at a remote site that communicates with the base station repeater.
RSCP	Receive Signal Code Power as applicable to Cellular
RSSI	Receive Signal Strength Indicator as applicable to UHF Narrowband and Spread Spectrum radios
RX Sensitivity	Radio Receiver sensitivity
Spread Spectrum Band	915 – 928 MHz
Store and Forward Repeater	A radio transmitter/receiver facility with packet storage capability that re-transmits each packet once the complete packet has been received.
Talk Through Repeater	A radio transmitter/receiver facility that immediately re-transmits data bits/bytes as they are received.
UHF Narrowband Radio	Licensed 12.5, 25 and 50 kHz radio modem or analogue radio operating in the 450 MHz band.
UTM	Universal Transverse Mercator

WGS84	World Geodetic System 1984
450 MHz Band	Shall be meant to include the 400 – 520 MHz frequency band as applicable to UHF Narrowband radios in this Standard

2 UHF Narrowband Radio Design

The following requirements shall apply to the design of all new and existing Water Corporation UHF Narrowband SCADA radio systems.

For exceptional sites, or shared sites with other organisations or government agencies, the ETSI radio site engineering EG 200 053 shall be used in conjunction with this standard – see References.

2.1 Design Objectives

The design of UHF Narrowband radio systems shall achieve the following objectives:

(a) Achieve reliable radio coverage of Water Corporation assets with the minimum number of base radio stations and point-to-point links;

(b) Minimise the cost of antenna support structures whilst achieving specified design fade margins;

(c) Minimise the interference between co-located radio systems;

(d) Satisfy specified performance objectives.

2.2 Radio Equipment

The design of UHF Narrowband radio links shall be based on the following equipment types and parameters.

2.2.1 Equipment Types

For all new 450 MHz systems the following radio equipment shall be used:

(a) For PMP and PP systems: 4RF SR+ ;

(b) PMP base stations: 4RF SR+ Full Duplex with external bandpass duplexer – optional 1+1 Protected (Redundant) Station;

(c) PMP remote stations: 4RF SR+ Half Duplex;

(d) PP links: 4RF SR+ Full Duplex with external bandpass duplexer – optional 1+1 Protected (Redundant) Station – optional Half Duplex linking for end of line / control link systems;

Alternative types of UHF Narrowband radio modems shall only be used if approved by the Water Corporation.

For expansion of an existing system the design shall be based on the use of compatible radio equipment.

2.2.2 Equipment Parameters

For all new 450 MHz systems the following radio equipment design parameters shall be used:

(a) PMP Base Radio TX Power - ACMA Limit = 40W EIRP into the antenna:

- +37dBm (5W);

(b) PMP Remote Radio TX Power - ACMA Limit = 20W EIRP into the antenna:

- +34dBm (2.5W) assuming 2dB typical losses and a 6 element yagi or;

(c) PP Link TX Power (into the antenna):

- +30dBm (1W) or;
- +20dBm (100mW) where the path is less then 10km

(d) Rx Sensitivity: -112 dBm for 10-6 BER at 25 kHz, 17.3kbps;

(e) Rx Sensitivity: -109 dBm for 10-6 BER at 50 kHz, 31.2kbps;

4RF SR+

ETSI / ACMA	Modulation	FEC	Radio Setting	12.5 kHz	Speed (kbps)	25 kHz	Speed (kbps)	50 kHz	Speed (kbps)
BER < 10-6	64 QAM	No FEC	64 QAM	-96 dBm	60.0	-92 dBm	120.0	-89 dBm	216.0
BER < 10-6	64 QAM	Min coded FEC	64 QAM Low Gain	-101 dBm	52.0	-97 dBm	103.9	-94 dBm	187.1
BER < 10-6	64 QAM	Max coded FEC	64 QAM High Gain	-103 dBm	45.6	-99 dBm	91.2	-96 dBm	164.2
BER < 10-6	16 QAM	No FEC	16 QAM	-102 dBm	40.0	-99 dBm	80.0	-96 dBm	144.0
BER < 10-6	16 QAM	Min coded FEC	16 QAM Low Gain	-108 dBm	23.1	-105 dBm	46.2	-102 dBm	83.2
BER < 10-6	QPSK	No FEC	QPSK	-108 dBm	20.0	-105 dBm	40.0	-102 dBm	72.0
BER < 10-6	16 QAM	Max coded FEC	16 QAM High Gain	-110 dBm	17.3	-107 dBm	34.6	-104 dBm	62.4
BER < 10-6	QPSK	Min coded FEC	QPSK Low gain	-113 dBm	11.6	-110 dBm	23.1	-107 dBm	41.6
BER < 10-6	QPSK	Max coded FEC	QPSK High Gain	-115 dBm	8.7	-112 dBm	17.3	-109 dBm	31.2

For expansion of an existing system the design engineer shall ensure that the relevant equipment parameters applicable to that system are used, including the correct TX power and RX sensitivity.

2.2.3 Receive Signal Level

The RSL shall be expressed as the Receive Signal Strength Indicator (RSSI) in dBm.

2.3 Antennas

The following sections contain the antenna gain, front-to-back ratio, bandwidth and polarisation requirements for the design of all new 450 MHz systems.

Note: Refer to Design Standard DS 42-03 for more detailed antenna requirements.

2.3.1 Point to Multipoint Systems

The requirements for point to multipoint antennas are as follows:

(a) The base station antenna shall be a vertically polarised omnidirectional antenna with a maximum gain of 8.2 dBi;

(b) For a remote station the following types of directional antenna should be used:

- In the 450 MHz band: a vertically polarised directional antenna with a mid-band gain of 11 dBi (eg a 6 element yagi);
- If higher gain yagis are used then the transmit power will need to be decreased

(c) A low profile panel mounted vertically polarised omnidirectional antenna may be used where the design shows that a suitable fade margin will be obtained. A 5W EIRP limit applies at Remotes when using an Omnidirectional antenna.

2.3.2 Point to Point Links

Point to point antennas shall meet the following ACMA RALI FX17 requirements:

In High and Medium Spectrum Density Areas:

(a) In the 450 MHz band: a directional antenna with a mid-band gain of at least 13 dBi, a minimum front-to-back ratio of 17 dB and a maximum beamwidth (in E-plane) of 36°;

Outside of High and Medium Spectrum Density Areas:

(b) In the 450 MHz band: a directional antenna with a mid-band gain of least 9 dBi, a minimum front-to-back ratio of 15 dB and a maximum beam width (in E-plane) of 45°;

Notes: The Perth Metropolitan area is designated by ACMA as a medium spectrum density area (as seen in Appendix E), while everything else in WA can be considered to be outside of high and medium spectrum density areas.
Not all manufacturers' yagi antennas meet the above specifications for gain, front-to-back ratio and beamwidth.

Antennas may be stacked to achieve higher gain.

Polarisation on point to point links should preferably be horizontal to minimise interference with point to multipoint radios systems.

2.4 Design Fade Margins

The following minimum design fade margins shall apply:

Path Length L	Minimum Design Fade Margin
L < 20 km	30 dB
20 km ≤ L < 40 km	35 dB
L ≥ 40 km	40 dB

The design fade margin shall apply to any RSSI calculated during design, including those based on propagation measurement results and those obtained from Pathloss software.

The design fade margin of each radio link shall be calculated as the difference in dB between the RSSI at the radio receiver and the manufacturers specified receiver sensitivity. The receiver sensitivity criteria shall be the 10^{-6} BER threshold for digital radio modems, unless otherwise agreed by the Water Corporation.

On each path, the designer shall aim for the highest possible fade margin consistent with meeting the minimum design fade margin, minimising antenna support structure costs and satisfying environmental requirements. A higher fade margin will always result in a more reliable radio path and potentially a higher throughput.

Where the measured design fade margin is different in each direction of transmission of a radio path, the lower value will be used for the path design.

A minimum operational fade margin that is 5 dB less than the minimum design fade margin will be acceptable during commissioning.

Note: Refer to Appendix A for reasons for the 5 dB difference between the design and operational fade margins.

2.5 Radio Path Analysis Parameters

The following radio path parameters shall be used for all UHF Narrowband designs:

(a) k-Factor: 1.33

(b) First Fresnel Zone Clearance: 0.6

The radio path will be considered to have free space path loss when it has clearance for 0.6 of the first Fresnel zone with a k factor of 1.33.

2.6 Radio Path Analysis Tool

Pathloss software shall be used for all SCADA radio desktop design work.

Note: Pathloss software is available from Contract Telecommunication Engineering Ltd. in Canada – refer to website.

2.7 Feasible Paths

The design engineer shall confirm that each radio path is a feasible path by undertaking one or more of the following:

(a) Desktop map study;

(b) An estimation of the path loss using Pathloss software – see Section 2.6; and/or

(c) Site visit.

Where a path is found to be unfeasible, the design engineer shall recommend one or more alternatives to radio.

Note: It is preferable that a desktop map study be undertaken prior to visiting site for a site survey, to ensure that when the site survey is carried out, maximum use is made of the time. For example if the desktop study establishes that the "prime" path is marginal, then alternative designs can be investigated and the alternative sites also surveyed on site.

2.8 Propagation Measurements

For UHF Narrowband and Spread Spectrum radios propagation measurements shall be undertaken on all feasible paths except where the following four conditions are satisfied:

(a) The path is < 20 km long; and

(b) The path is line of sight; and

(c) The predicted fade margin is at least 30dB; and

(d) It is not proposed that a low profile antenna be used.

On these paths, Pathloss software shall be used to estimate the RSL.

Note: Line of sight paths do not include paths where the far site can be seen through trees.

The propagation measurements shall meet all requirements specified in Work Instruction WI 42-01.

See Appendix B for further information on propagation measurements and the risks associated with the use of low profile antennas.

2.9 Reflection Analysis

Reflection analyses shall be carried out on paths that the design engineer considers may support specular reflections. Reflections may occur where paths pass over water or flat terrain, especially terrain that is subject to inundation.

Antenna heights shall be chosen to avoid more than 3dB signal median depression due to reflections, for all expected k values. Up to 6 dB signal enhancement due to reflections at the receive antenna shall be considered as acceptable for SCADA links.

Pathloss software shall be used for reflection analysis. The analysis shall include RSL versus antenna height and k factor plots for each antenna.

2.9.1 Reflection Protection Measures

Reflection protection measures shall include, but not be limited to, use of the following:

(a) Choosing antenna heights so as to avoid signal cancellation due to a reflection;

(b) Using a spatially diverse antenna configuration.

2.10 Radio Interference Protection

Radio interference studies shall be carried out where, in the opinion of the design engineer, one or more of the following types of interference are likely occur:

Type 1. Site interference between radios collocated on the same site, or within a radius of 4km.

Type 2. Overshoots within the same system, ie between sites located long distances apart (up to hundreds of kilometres) where ACMA has reassigned the same frequencies.

Type 3. Mutual interference between the SCADA and other radio systems.

Note: During the new frequency assignment process, ACMA allocates frequencies that will avoid most types of interference and no further interference study will be required. However, there may be circumstances where the design engineer decides that additional analysis and interference protection is required, for example where the radio system is to be upgraded using existing frequencies, or where known ducting can cause potential long distance overshoots.

Type 1 interference studies shall be carried out in accordance with Section 2.10.1. Type 2 and 3 interference studies shall be carried out during frequency planning, in accordance with Section 2.10.2.

2.10.1 Radio Site Interference

Type 1 radio interference studies shall be carried out for all multi transmitter radio sites and sites where other transmitters are located within 4km. The interference studies shall include identification of potential interference from existing radio system(s) into the proposed new system, and interference from the proposed new system into existing collocated radio system(s). The interference studies shall include identification of potential:

(a) Intermodulation products that may interfere with the proposed new receiver signal(s);

(b) Intermodulation products generated by the proposed new transmitter that may interfere with existing collocated radio systems;

Note: Intermodulation calculations should include up to at least 5th order products.

(c) Interference and/or blocking of the proposed new receiver(s) that may be caused by existing transmitter(s) collocated at, or adjacent to, the site; and

(d) Interference and/or blocking of existing collocated radio systems that may be caused by the proposed new transmitter.

Note: The mandatory use of bandpass duplexer filters at base station sites will prevent most Type 1 interference.

2.10.2 Frequency Planning

Frequency planning shall be undertaken to avoid Type 2 and/or 3 interferences. This shall be done in conjunction with ACMA or its agent when new frequency assignments are sought. The frequency assignments shall be planned and coordinated in accordance with ACMA requirements contained in RALI FX16 and RALI FX17.

2.10.3 Interfering Signal Levels

All in-band intermodulation and/or unwanted co-channel interference signal levels shall be at least 6dB below the relevant receiver mute level setting. Interference protection equipment shall be provided where any in-band intermodulation and/or unwanted co-channel interference signal level is higher than 6dB below the relevant receiver mute level setting.

The sum of all unwanted adjacent channel interference signals shall be no more than -17dBm to avoid receiver blocking. Interference protection equipment shall be provided where the sum of all out-of-band interference signals is higher than -17dBm.

If there is an unacceptable level of interference the guidelines described in Section 13 (Trouble Shooting on Radio Sites) ETSI EG 200 053 V1.5.1 (2004-06) shall be used.

2.10.4 Interference Protection Measures

All equipment necessary to reduce interference from existing radio system(s) into the proposed new system shall be included in the design. Interference from the proposed new system into existing collocated radio system(s) shall be reduced to acceptable level(s). See Section 7.3.

Interference protection measures shall include, but not be limited to, use of the following:

(a) Radio frequency filters;

(b) Circulators and isolators;

(c) Double-screened antenna feeder cables;

(d) Antenna cross polarisation, separation and orientation; and

(e) Alternative radio frequencies.

Refer to ETSI EG 200 053 V1.5.1 (2004-06) Annexes H to M for more information and measurement procedures.

2.11 Radio Design Deliverables

Radio final design reports shall be prepared in accordance with WI 42-01.

2.12 Independent Design Review

For a Major Design, the final radio design shall be submitted for review by an independent reviewer.

3 Cellular Radio Design

The following requirements shall apply to the design of all Water Corporation Cellular radio links.

3.2 Design Objectives

The design of Cellular radio systems shall achieve the following objectives:

(a) Achieve reliable radio connection to the Water Corporation SCADA and Corporate WANs;

(b) Minimise the cost of antenna support structures whilst achieving the specified design RSCP – see Section 3.4 for the design RSCP;

(c) Satisfy specified performance objectives.

3.3 Radio Equipment

The following equipment types shall be used for Cellular SCADA applications:

- CDCS CDM882SEU or CDR780SEU modems or direct replacement types as approved by the Water Corporation.

An alternative brand of Cellular modem shall only be used if approved by the Water Corporation.

Note: The Corporation has approved the use of the CDCS modems following extensive field trials and evaluation. The use of alternative brand modems will require similar trial and evaluation.

3.3.1 Receive Signal Level

The RSL shall be expressed as the Receive Signal Code Power (RSCP) in dBm.

Note: For Cellular, RSCP is not the same as RSSI, the two being related as follows:

RSCP (dBm) = RSSI (dBm) + Ec/Io (dB)

where Ec/Io is the Pilot Signal Energy/Total In-band Energy.

3.3.2 Antennas

Cellular antennas shall meet the following requirements:

(a) In areas where Cellular coverage is suitable: A vertically polarised high gain omnidirectional antenna;

(b) In marginal/fringe areas: A vertically polarised high gain directional antenna.

Note: A marginal/fringe area is defined as one where the design RSCP cannot be achieved with a high gain omnidirectional antenna mounted on a pole ≤ 20m high.

3.4 Design RSCP

A minimum design RSCP is specified that is 5 dB higher than the operational RSCP. This is done to accommodate expected variations between the design and final path RSCP.

Cellular links shall be designed to achieve a minimum pilot channel RSCP of -85 dBm in the downlink direction of transmission.

A minimum operational Cellular RSCP of -90 dBm will be acceptable during commissioning.

3.5 Ec/Io

As specified in Work Instruction WI 42-02, Cellular Ec/Io shall be measured at all sites.

Where the Ec/Io is less than -10 dB due to pilot noise pollution, corrective action shall be taken as specified in Work Instruction WI 42-02.

3.6 Radio Path Analysis Parameters

The following radio path parameters shall be used for all Cellular desktop designs:

(d) k-Factor: 1.33

(e) First Fresnel Zone Clearance: 0.6

The radio path will be considered to have free space path loss when it has clearance for 0.6 of the first Fresnel zone with a k factor of 1.33.

3.7 Radio Path Analysis Tools

Pathloss Version 4.0 software shall be used for all SCADA radio desktop design work.

Notes: Pathloss desktop RSCP(s) will generally be approximate and unsuitable for final design purposes. Refer to Work Instruction WI 42-02 for further details.

Pathloss software is available from Contract Telecommunication Engineering Ltd. in Canada – refer to website.

3.8 Feasible Paths

The design engineer shall confirm that each Cellular radio path is feasible in accordance with Work Instruction WI 42-02.

3.9 Cellular Signal Level Measurements

Signal level measurements shall be undertaken on all Cellular paths.

Note: All Cellular paths are to be measured, irrespective of whether or not they are line of sight, in order to determine Ec/Io.

Cellular signal level measurements shall be undertaken in accordance with Work Instruction WI 42-02.

See Appendix B for further information on measurements and the risks associated with the use of low profile antennas.

3.10 Radio Design Deliverables

Cellular radio final design reports shall be prepared in accordance with Work Instruction WI 42-02.

4 Spread Spectrum Radio Design

The following requirements shall apply to the design of all standard Water Corporation Spread Spectrum SCADA radio systems.

Note: There is a relatively high risk that Spread Spectrum radio systems will suffer from other user interference. This standard stresses the importance, as part of the design of a reliable system, of identifying an effective organisational network management unit that will be responsible for responding rapidly and rectifying the impact of unacceptable interference from other users on an ongoing basis.

4.2 Design Objectives

The design of Spread Spectrum radio systems shall achieve the following objectives:

(a) Achieve reliable radio coverage of Water Corporation assets with the minimum number of base radio stations and point-to-point links;

(b) Minimise the cost of antenna support structures whilst achieving the specified design RSSI – see Section 4.5 for the design RSSI;

(c) Establish a plan for effective Spread Spectrum network management;

(d) Satisfy specified performance objectives.

4.3 Scope of Application

Spread Spectrum radios shall be used for SCADA only under the following circumstances:

(a) For user data rates up to 19,200 bps: where a UHF Narrowband licensed radio frequency assignment in all of the relevant 450 and 900 MHz bands is unobtainable from ACMA, eg due to congestion; or

(b) For user data rates in excess of 19,200 bps: where it is shown to be uneconomical to use licensed-band radios; and

(c) The equipment type shall be as specified in Section 4.4; and

(d) The design RSSI and maximum EIRP are achieved as specified in Sections 4.5 and 4.4.2, respectively; and

(e) An organisational unit is identified that will be responsible for effective Spread Spectrum network management as specified in Section 4.6.

4.4 Radio Equipment

The equipment types used for Spread Spectrum SCADA applications is under review. This document will be updated when the equipment has been approved for use.

Alternative types of Spread Spectrum radios shall only be used if approved by the Water Corporation.

4.4.1 Receive Signal Level

The RSL shall be expressed as the Receive Signal Strength Indicator (RSSI) in dBm.

4.4.2 Antennas

Spread Spectrum PMP network and PP link antennas shall be chosen to:

(a) Meet the safe radiation distances and structural requirements of DS 42-03, Section 2.2;

(b) Limit the maximum EIRP - see Section 4.4.3.

Note: There are no other specific requirements for the gain or polarisation of Spread Spectrum antennas.

4.4.3 Maximum EIRP

The maximum EIRP shall be 1W (+30dBm) at all locations.

The EIRP shall be calculated as follows:

EIRP (dBm) = TX Power (dBm) + Antenna Gain (dBi) – Feeder System Losses (dB).

4.5 Design RSSI

A minimum design RSSI is specified that is 5 dB higher than the operational RSSI. This is done to accommodate expected variations between the design and final path RSSI.

Spread Spectrum PMP and PP links shall be designed to achieve a minimum RSSI of -75 dBm in both directions of transmission.

The design RSSI of -75 dBm shall apply in urban and country applications.

A minimum operational Spread Spectrum RSSI of -80 dBm will be acceptable during commissioning.

4.6 Network Management

There is a high risk that interference from other users will cause serious performance degradation to SCADA Spread Spectrum systems.

The Spread Spectrum design report shall contain a network management plan that shall include, but not be limited to, all of the following details:

(a) Identification of the organisational unit that will be responsible for the ongoing Spread Spectrum network management; and

(b) How the performance of the Spread Spectrum system will be monitored; and

(c) How the presence of unacceptable interference from other users will be detected; and

(d) What action the organisational unit may take to rectify the interference problem.

Note: It is strongly recommended that Spread Spectrum radio should not be implemented without such a network management organisational unit in place that will respond rapidly to effectively rectify the impact of interference.

4.7 Design Procedures

The design procedures for radio path analysis parameters, radio path analysis tools, feasible paths, propagation measurements, radio design deliverables and independent design review shall be as specified in Sections 2.2 to 2.8, and 2.11 and 2.12 of this standard.

5 Appendix A Minimising Risks Associated with Radio Design

(Information Only)

Radio network designs always have an element of risk as the atmosphere is used as the transmission media and cannot be controlled to the same extent as guided media such as copper or fibre cable. Added to this risk are:

- Errors that can arise from RSL predictions;
- RSL variations due to the effects of vegetation and buildings on the radio transmission, particularly for the type of point to multipoint networks used by the Water Corporation.

These risks need to be managed as discussed in the following sections.

5.2 RSL Predictions

Predicting the RSL on an obstructed path using Pathloss is risky and will often lead to errors. This is because the software diffraction and clutter loss algorithms yield approximations to the actual loss.

Predicting loss on an apparently line of sight path can be risky as line of sight is not a guarantee of an unobstructed path. Assuming that a path is unobstructed because it is line of sight can lead to serious errors in estimating the RSL on paths of 20 km or more.

Experience with low profile antennas has shown that large RSL errors can occur even on line of sight paths. The correct positioning of low profile antennas is critical.

In order to minimise the risks associated with UHF Narrowband and Spread spectrum RSL predictions, this standard mandates that propagation measurements are required on all but < 20 km line of sight paths that have a calculated fade margin of at least 30 dB with a yagi antenna (ie not low profile antenna).

5.3 RSL Variations

Measuring radio paths for design purposes reduces the risk of error but does not eliminate it. Variations between measured and installed RSL can still happen. Reasons for the variation between what is measured and the final installed system include the following:

1. Path Loss Variations. Variation in atmospheric conditions and signal scatter loss through trees and other clutter on the path as the weather changes. RSLs can be logged or charted over a period of time to better predict these variations, but this is time consuming and costly, and not often done.

2. Trees and Buildings. Tree growth and/or new buildings on paths that increase the path loss.

3. Site Spatial RSL Variations. In most cases the installed antenna is not located in exactly the same position as the test antenna and the RSL can vary from the measured figure.

4. Other Equipment Variations. Excessive loss can occur in feeder cables, connectors, duplexers, and surge suppressors due to water ingress, mechanical damage and/or incorrect installation. These are usually corrected during commissioning.

Water Corporation experience has shown that in most cases the RSL variations due to items 1 to 3 above do not exceed ± 5dB. The variations can be taken into account by using design RSLs that include an extra 5dB above the required operational RSLs. This approach significantly reduces the risk of a path not meeting the required operational RSL, at an acceptable cost.

6 Appendix B UHF Narrowband Radio Design Information

(Informative)

The aim if this section is to provide the design engineer with some background to the UHF Narrowband radio design standards.

6.2 SCADA Paths

The UHF Narrowband SCADA paths that this standard applies to will fall into one of the following categories:

6.2.1 Type 1

Less than 20km with clear through to badly obstructed paths. Most point-to-multipoint network paths fall into this category. The base station will usually be well located in a high position with good foreground clearance. The remote sites may be in locations with clear line of sight through to those with obstructing terrain, buildings and/or poor foreground clearance due to trees.

6.2.2 Type 2

Between 20 and 40km and mostly unobstructed. These paths will be clear to mildly obstructed with higher than free space path loss. These paths may be PMP but will more likely be PP. These paths will require higher antennas to overcome obstructions, which usually limits their application to mildly obstructed scenarios.

6.2.3 Type 3

Greater than 40km and essentially unobstructed. These paths will almost certainly be point-to-point with close to free space path loss. In situations where the path is obstructed, consideration should be given to utilising a back-to-back repeater.

6.3 Receive Signal Level (RSL) Variations

The RSL at the radio receiver input will vary as a result of the following:

6.3.1 Path Loss Variations

Variations in path loss will occur due to changes in atmospheric conditions and signal scatter loss through trees as the weather changes. Tree growth and/or new buildings on paths may also increase the path loss.

6.3.2 Site Spatial Variations

Reflections and scatter can cause RSL standing wave patterns at the site. Moving the site antenna a relatively small distance (about one-half wavelength or 330mm at 460 MHz) can result in an RSL variation. This effect is complicated further because the standing wave pattern varies with time as the atmospheric conditions change, hence there is no one “best” antenna / pole position. These are long term effects and the RSL variations are usually described by a log-normal probability distribution. The UHF Narrowband design fade margins include an extra 5dB to allow for site spatial and path loss variations.

6.3.3 Multipath Fading

This is due to many signals arriving simultaneously at the receive antenna with different amplitudes and phase delays. They add vectorially and can cause rapid deep fades of RSL to below the radio modem receiver threshold. Multipath fading is short term and is usually described by a Rayleigh probability distribution. The specified fade margin is provided to minimise outages due to multipath fading.

6.3.4 Reflections

Reflections may occur where paths pass over water or flat terrain. A strong reflected signal may interfere with the direct signal at the receive antenna. The direct and reflected signals may interact constructively or destructively. In worst case scenarios, severe destructive fading below receiver threshold may last for hours at a time. Antenna heights can be chosen to avoid most reflective fading. Hence during design, the selection of correct antenna heights on a potentially reflective path is critical.

6.3.5 k-Factor Fading

This occurs when atmospheric refractive index conditions cause the radio signal to be bent upwards more than normal. This is equivalent to a decrease in k-factor and an increase in the earth bulge into the rayline. The additional path loss caused by the increased earth bulge can cause long term median signal depression and even outage. Designing for path clearance under minimum k-factor conditions (ie maximum earth bulge) will require high antenna support structures. Fortunately, severe k-factor fading does not occur frequently for long periods and is not taken into account during SCADA radio design. All Water Corporation SCADA path designs allow for clearance with a “normal” k-factor of 1.33. The multipath fade margin described above will provide limited protection from k-factor fading.

6.3.6 Ducting and Inversions

This occurs when atmospheric refractive index conditions cause layering that “traps” or reflects the radio signal. This in turn can cause signal enhancement at the receiver, fading or even outage due to rayline cutoff. Ducting and inversions are difficult to predict and are not taken into account during Corporation SCADA radio design, other than by selecting frequency assignments that will avoid potential long distance overshoots due to ducting.

6.3.7 Faulty Equipment

Excessive loss can occur in feeder cables, connectors, duplexers, and surge suppressors due to water ingress, mechanical damage and/or incorrect installation. No allowance is made for faulty equipment during radio path design. It is expected that radio diagnostics will provide trends that indicate the condition of the equipment for operational purposes, for example TX power, frequency, and RSSI.

6.4 Fade Margins

As previously mentioned, the specified fade margin provides protection from multipath fading. The fraction of time P that the depth of multipath fade will exceed the fade margin is given by the following expression:

$$P = k.f.d^3.10^{\left(\frac{-FM}{10}\right)} \quad \text{……………………………………..[1]}$$

where: k = an empirically derived constant

f = frequency

d = path distance

FM = fade margin in dB.

When the depth of multipath fade exceeds the fade margin, the radio link will experience an increasingly high bit error rate. At some point the link will become unusable and a transmission outage will occur.

Because P is proportional to distance cubed, different design fade margins are specified for various lengths as per Section 2.4 of the Standard. Figure 1 shows typical values of P for the worst month (summer) and a full year, using the specified operational fade margins. Note that P is for both directions of transmission over a radio link.

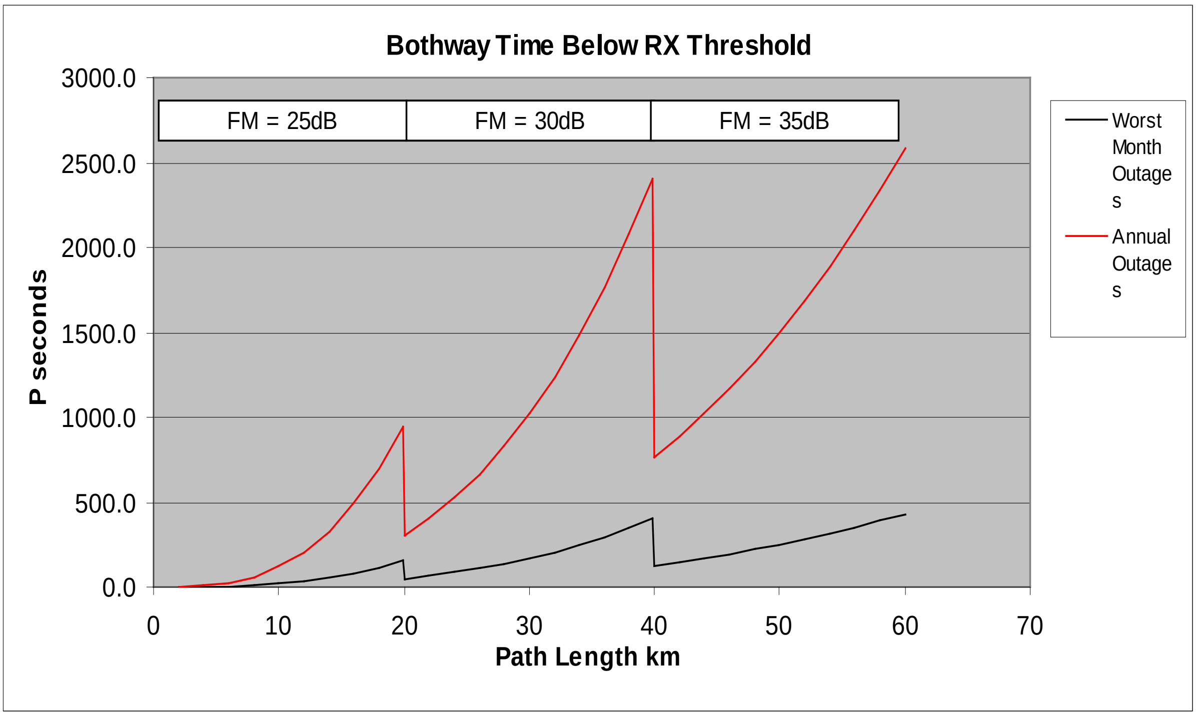


Figure 1 - Estimated worst month and annual time RSL will be below receiver threshold due to multipath fading for both directions of a typical 500MHz data radio system with the operational fade margins shown.

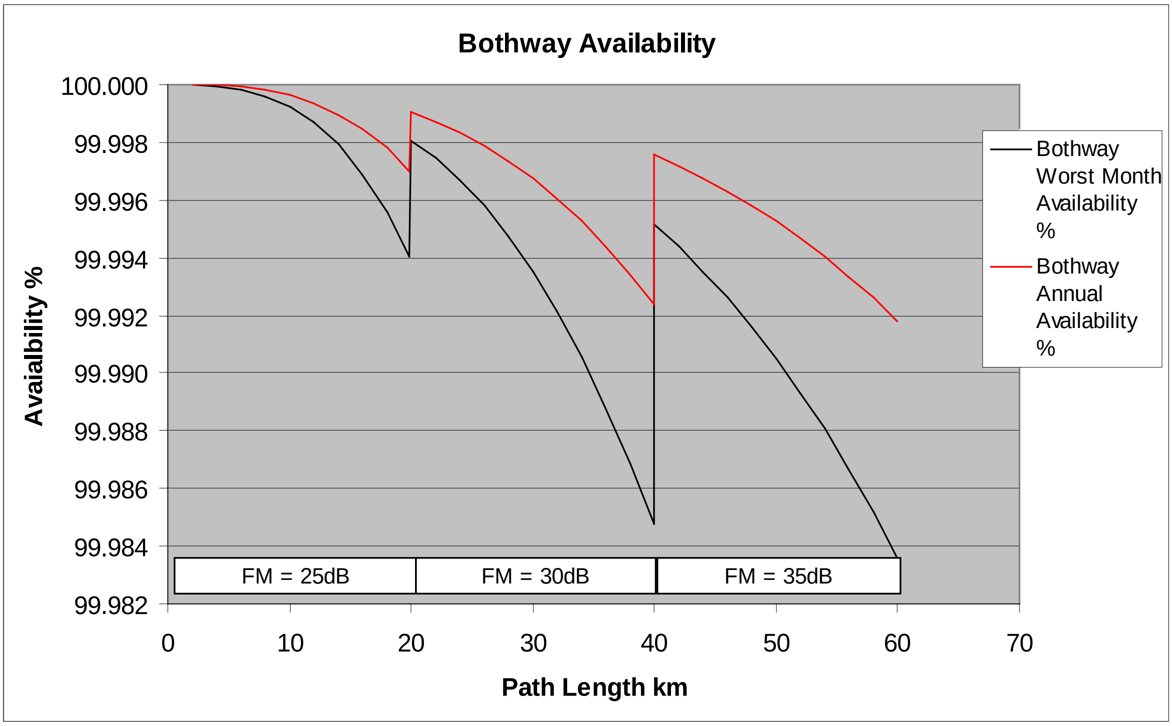


Figure 2 - Estimated worst month and annual availability due to multipath fading for both directions of a typical 500MHz data radio system with the operational fade margins shown.

Figures 1 and 2 were calculated using equation [1] with k derived from the Vigants - Barnett fade probability C-factor for paths in areas with difficult propagation conditions. Figure 2 shows typical both way system availability due to multipath fading. The availability calculation makes no allowance for the length of time the RSL remains below the receiver threshold, or how long the radio link takes to resynchronize after an outage. That is, using an equation based on [1] above to determine system availability is an approximation.

Figures 1 and 2 suggest that the specified fade margin for paths of 20km or less could be relaxed from 25 to around 20dB. This would bring the values of P and availability into a similar range as for paths of greater than 20km, respectively. However, it is considered that 25 dB provides a greater margin for tree growth on Type 1 paths and is hence retained.

6.5 Meeting Fade Margins

In some cases it will be difficult to meet the specified design fade margin without using excessively high antenna support structures. The question arises: how rigidly should the design fade margin be applied?

It can be seen from Figures 1 and 2 that if the path length is slightly above either of the step transitions at 20 and 40 km, the design fade margin can be relaxed from 35 or 40 dB, respectively.

Conversely, if the path length is slightly below either of the step transitions at 20 and 40 km, the design fade margin should not be relaxed from 30 or 35 dB, respectively.

Operational knowledge obtained from existing radio paths may provide some indication of the probability of occurrence of multipath fading in an area.

The risks associated with not meeting the specified fade margin include the possibility of having to upgrade the radio system at considerable cost.

Where practical, the designer should aim for higher than specified fade margins. The higher the fade margin, the better the link will perform.

The downside of using higher poles and higher gain antennas to achieve higher fade margins includes additional cost, problems with environmental issues such as visual impact and vandalism. The design engineer must strike a balance.

6.6 Interference

During the new frequency assignment process, ACMA allocates frequencies that will avoid most types of interference. ACMA searches for all transmitters within a 4km radius and calculates potential Type 1 interference, including 3rd and 5th order intermodulation products. ACMA searches for other assignments within a 100 and 200km radius for point to multipoint systems and point to point links, respectively, and calculates potential Type 2 & 3 interference. See ACMA RALI FX16 and RALI FX17 for further frequency assignment requirements.

The ACMA assignment process will avoid most unacceptable interference; however there may be circumstances where the design engineer decides that additional analysis and interference protection is required, for example where the radio system is to be upgraded using existing frequencies, or where known ducting can cause potential long distance overshoots, particularly between point to point links on a long pipeline SCADA system.

The standard states that: “All in-band intermodulation and/or unwanted co-channel interference signal levels shall be at least 6dB below the relevant receiver mute level setting.” It can be shown that if this condition is met, the receiver sensitivity will not be degraded.

The standard states that: “The sum of all unwanted adjacent channel interference signals shall be no more than -17dBm to avoid receiver blocking.” This figure was provided by 4RF for their SR+ range of radio modems.

6.7 Fresnel Zone Clearance

There is a relationship between Fresnel zone clearance and RSL interference on a path that supports ground reflections.

When a reflective path has clearance for 0.6 of the first Fresnel zone ($0.6F_1$) the reflected signal does not cause interference at the receive antenna and the path will have free space loss.

When a reflective path has clearance for all of the first Fresnel zone ($1.0F_1$) the reflected signal causes up to 6 dB RSL enhancement at the receive antenna.

When a reflective path has clearance for all of the first and second Fresnel zones ($1.0F_2$) the reflected signal can cause complete RSL cancellation at the receive antenna.

For higher orders of Fresnel zone clearance this process continues with up to 6 dB enhancement or RSL cancellation with even and odd Fresnel zone clearances, respectively.

The degree of RSL enhancement or cancellation will depend on the extent of the ground reflection. Where 100% reflection is possible, for example over water, the path RSL will experience alternate 6 dB enhancement and complete cancellation as the height of the receive antenna is raised, and path clearance passes through an increasing order of Fresnel zones.

The Fresnel zone clearance also depends on the path k-factor. As the k-factor varies, the RSL will experience RSL enhancements and cancellation as the path clearance passes through changing orders of Fresnel zones.

As a general rule of thumb, keeping the antenna heights low and taking advantage of terrain protection will provide ≤ $0.6F_1$ path clearance and avoid severe RSL cancellation. This is not always possible on high antenna to low antenna reflective paths and the designer must carefully select antenna heights to avoid RSL cancellation under conditions of a normal k-factor.

6.8 Line of Sight Paths

Line of sight is not a guarantee of an unobstructed path. The Fresnel zone clearance may be less than required. In the worst case the radio ray line could be approaching grazing on a flat earth where the diffraction loss could be more than 20 dB. On paths of up to 20 km this additional loss does not usually pose a serious risk as the signal strength is relatively high and the specified fade margin is relatively low. On longer line of sight paths, however, there is less margin for error and propagation measurements are required.

Line of sight paths do not include paths where the far site can be seen through trees. Trees will introduce clutter loss, which is difficult to predict using PATHLOSS. Experience has shown that clutter loss can be significant, and propagation measurements are required.

6.9 Low Profile Antennas

Experience with low profile antenna measurements has shown that large RSL variations can occur even on line of sight paths. The positioning of a low profile antenna, for example on top of a cubicle, is critical and should be done when measuring the RSL.

7 Appendix C Cellular Radio Design Information

(Informative)

The aim if this section is to provide the design engineer with some background to the Cellular radio design standards.

7.2 General

NextG is a third generation (3G) cellular network operated by Telstra. It employs direct sequence wideband spread spectrum transmission, various coding, modulation and error correction schemes, and has adaptive performance to cope with widely varying operating conditions.

Cellular operates in the following frequency bands:

Downlink (base Tx): 870 – 890 MHz

Uplink (base Rx): 825 – 845 MHz

Cellular features automatic handover between base stations, providing redundancy in most SCADA applications. Cellular provides static IP address connectivity to the Water Corporation SCADA WAN, and allows peer-to-peer IP networking.

All Telstra Cellular base stations transmit in the same band. Other Telcos transmit in adjacent bands. Each base station transmits a constant power pilot channel reference signal. The measurement of pilot channel RSCP forms the basis of Cellular design.

The Cellular service is currently asymmetrical, with the uplink slower than downlink. The theoretical maximum data rates are 14.4 and 1.9 Mbps for the downlink and uplink, respectively. Practical data rates are in the range 500 kbps – 1 Mbps for the downlink and 250 – 500 kbps for the uplink. It is expected that these data rates will continue to increase as the 3G technology develops.

The user data throughput rates are strongly limited by the SCADA protocol used, for example DNP3, interference from other Cellular pilot signals (pilot pollution) and the cell site/network traffic loading. The pilot pollution and user loading is covered in more detail in the following section on Ec/Io.

7.2.1 Ec/Io

The Ec/Io is defined as the ratio of pilot signal energy to the total energy in the receive band. The total energy includes all pilot channels and all user channels from all base stations and noise.

Ec/Io is expressed in dB, where the value is typically negative indicating that the pilot signal energy is less than the total energy in the band, ie the pilot is “buried” in noise + interference.

Ec/Io is a measure of pilot pollution, system traffic loading and, more indirectly, quality of service. As the unwanted pilot pollution and/or user traffic loading increases the Ec/Io becomes worse. This can cause the quality of service to degrade and in turn user throughput decreases and latency increases.

Ec/Io is also related to the pilot channel RSCP. As the wanted pilot signal energy decreases the quality of service can decrease as the Ec/Io becomes worse. It is therefore important to maintain a suitably high pilot RSCP for the best quality of service.

Most Cellular SCADA installations will use an omnidirectional antenna that will “see” multiple pilot signals. These have the potential to cause excessive pilot pollution which can degrade the quality of service.

The measurement of Ec/Io is a fundamental component of Cellular design. It has been found in practice that where the Ec/Io is better than -10 dB, the level of pilot pollution will be acceptable.

Means whereby the Ec/Io can be kept above -10 dB are covered further in Work Instruction WI 42-02.

7.3 Basis of -85dBm Design RSCP for Cellular networks

It has been determined that an RSCP design level of -85dBm or better will ensure that:

- Maximum data throughput performance is achieved for at least 99.9% of any month;

- The radio path availability is at least 99.99% in any month;

- Ec/Io is maximised.

These conclusions were derived from depot measurements, 3G publications and a field trial. The depot measurements, carried out on a typical Cellular modem, determined that:

- The Cellular uplink performance is not as good as the downlink performance, effectively limiting the overall Cellular service performance to that of the uplink;

- The minimum modem receiver threshold level required to provide reliable uplink service and ensure maximum data throughput was -100 dBm;

- Below this threshold level, the data throughputs and latencies could be expected to degrade, and at sufficiently low signal level the modem would disconnect and cease to provide any service.

Figure 3 shows the modem uplink threshold and region of decreasing performance as the RSCP decreases. The aim of Cellular design is to keep the RSCP above the -10 dBm threshold for at least 99.9% of the time.

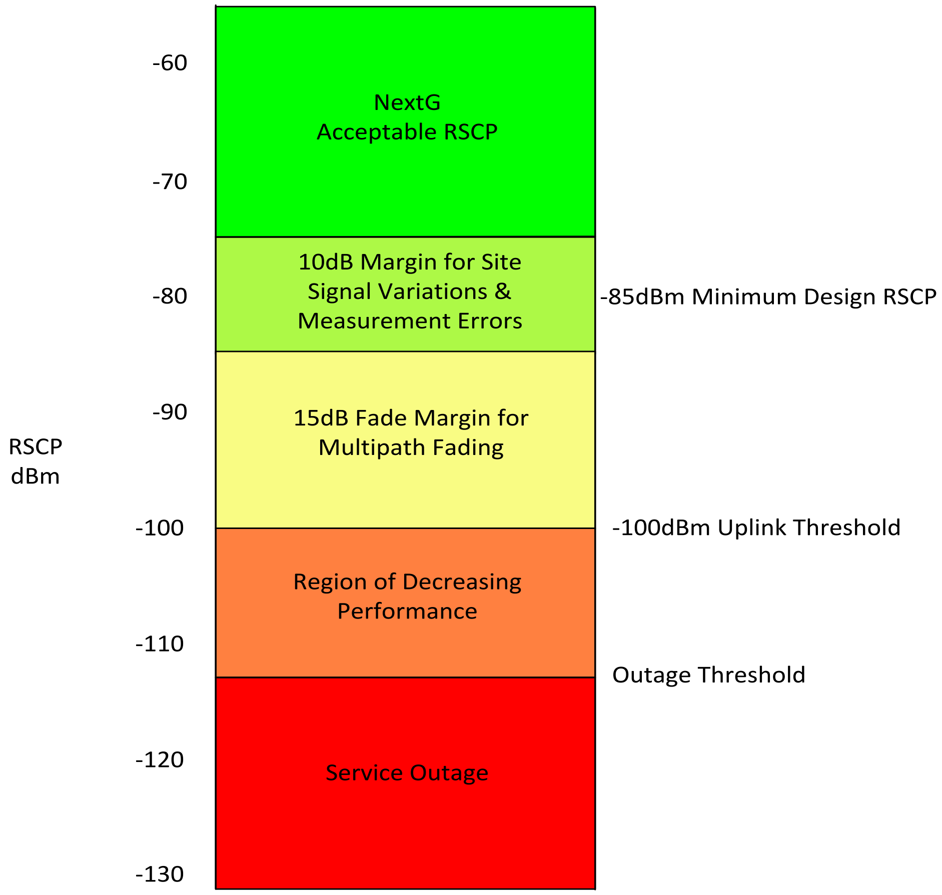


Figure 3 Relationship between Cellular RSCP and throughput performance.

Published data indicates that RSCP variations will be encountered at a typical remote location due to the effects described in Section 6.3.2 of this Standard.

In most cases the installed antenna is not located in exactly the same position as the radio survey test antenna and the RSCP can vary from the measured figure. There can also be measurement errors.

In all a 10 dB site margin for signal variations and measurement errors is allowed as shown in the above figure.

Using results from an extended CDMA field trial it was concluded that a further 15 dB fade margin should be allowed for multipath fading.

Taking all of the above factors into account, the mandated minimum design RSCP of -85 dBm is arrived at as follows:

Design RSCP (dBm) = Uplink Threshold (dBm) + Site Margin (dB)

8 Appendix D Spread Spectrum Radio Design Information

(Informative)

The aim if this section is to provide the design engineer with some background to the Spread Spectrum radio design standards.

8.2 General

Spread Spectrum radios generally operate under an ACMA Low Interference Potential Device (LIPD) class licence. Other users operate in the same spectrum segment on a shared basis and are subject to the same conditions. A class licence governs the frequencies that may be used, commonly prescribes equipment standards, and may specify other technical and operational parameters such as TX power. Class licences do not have to be applied for, and no licence fees are payable.

The following table shows the ACMA frequency bands and power limits for spread spectrum and digital modulation devices.

Device	Frequency Band (MHz)	Maximum EIRP
Frequency hopping transmitters and digital modulation transmitters	915 to 928	1 W *(frequency hopping transmitters must use a minimum of 25 hopping frequencies)*
Frequency hopping transmitters	2400 to 2483.5	500 mW *(a minimum of 15 hopping frequencies must be used)*
Frequency hopping transmitters and digital modulation transmitters	2400 to 2483.5	4 W *(frequency hopping transmitters must use a minimum of 75 hopping frequencies)*
Frequency hopping transmitters and digital modulation transmitters	5725 to 5850	4 W *(frequency hopping transmitters must use a minimum of 75 hopping frequencies)*

8.2.1 Scope

This Standard applies to Spread Spectrum radios that employ frequency hopping and operate in the 915 to 928 MHz frequency band.

Other types of Spread Spectrum radios that employ either frequency hopping or direct sequence modulation and/or operate in other frequency bands are outside of the scope of this Standard.

8.2.2 Comparison with UHF Narrowband Radio

Spread Spectrum radios operate with higher radio data bit rates and wider radio channel bandwidths than current SCADA UHF Narrowband radios. Whereas the Spread Spectrum system shares its operating bandwidth with many other users, a UHF Narrowband system enjoys exclusive use of a radio channel by virtue of its regulated licence conditions.

The maximum EIRP of spread spectrum radio installations allowed by ACMA is also less than allowed for UHF Narrowband radio. Antenna gain, feeder loss and radio TX power must be chosen to ensure that the EIRP is not exceeded.

8.3 Throughput and Latency

With sufficiently high signal to noise ratio (SNR) the high bit rate will enable Spread Spectrum radios to transmit SCADA frames at a relatively high rate. As the SNR is decreased, errors will occur and radio frames will be lost.

The Trio Spread Spectrum radios incorporate automatic retransmission of errored radio frames. The maximum number of radio frame retries can be set, typically to five, after which the SCADA frame will be discarded. Provided that the number of retries does not exceed the maximum allowed, no SCADA frames will be lost.

The point at which retransmissions commence is called the retry threshold. As the number of retries increases, more of the radio bandwidth is used for retransmissions. The SCADA frame rate will decrease and the latency will increase. It is important that adequate SNR is maintained to ensure that the Spread Spectrum retransmissions do not cause significant degradation of SCADA user traffic.

The increase in retransmissions is a gradual process occurring over a wide range of SNR, typically 10dB or more. When the maximum number of retries is exceeded, the frame threshold will be reached and SCADA frames will be lost. Below this frame threshold the Spread Spectrum link will be degraded further with increasing user frame loss and eventually become unusable.

The latency will also depend on the radio type and configuration. For example the radios operate in half duplex mode where frame transmission alternates between transmit and receive mode and latency will partly depend on time slot availability. With multiple frame retries occurring the latency can be expected to increase up to fivefold. A full description of Spread Spectrum radio equipment and configuration latency is complex and beyond the scope of this standard.

8.4 Bandwidth, Noise and Interference

Because of the wider transmission bandwidth as compared to licensed SCADA UHF Narrowband radio, Spread Spectrum is high risk technology that is more susceptible to noise and interference. Spread spectrum systems must be designed to operate in noisy and interference prone environments.

The design must ensure that the receive SNR is adequate for reliable, error free operation. Here the SNR is the ratio of wanted signal energy (expressed as RSSI in dBm) to the total noise energy in the receiver bandwidth. The total noise energy includes all types of interference from other users in the band

For most Spread Spectrum applications the radio link performance is fundamentally determined by the level of interference at the receive site. This is different from UHF Narrowband radio systems which are designed to operate in a relatively interference free environment and the radio link performance is fundamentally determined by the radio equipment receiver threshold.

As a consequence the Spread Spectrum standard specifies the minimum RSSI that must be achieved, whereas the UHF Narrowband Standard continues to specify the minimum fade margin based on the equipment type receiver threshold.

Specifying the minimum Spread Spectrum design RSSI is consistent with specifying the minimum Cellular design RSCP.

8.5 Fade Margin

Because of the wider transmission bandwidth as compared to SCADA UHF Narrowband radio, Spread Spectrum is less prone to multipath fading. As a result, less fade margin is required.

8.6 Measuring the Impact of Interference

Because of its random nature, measuring the impact of interference in the Spread Spectrum band is difficult and needs to be undertaken on a continuing basis. The Trio radio pseudo random frequency hopping pattern is superimposed on randomly generated interference. The instantaneous SNR will continually vary over a wide range, possibly causing radio frame loss in some frequency slots and not in others.

There is no guarantee that the measured performance of a Spread Spectrum radio during a field survey will apply in the future. For example, another Spread Spectrum user may set up nearby and legally generate high levels of interference, well in excess of that measured during the survey, and cause serious performance degradation or even system outage.

Experience in the US shows that Spread Spectrum systems in highly congested urban areas must be continually monitored and managed to ensure acceptable performance. This is one of the costs of employing high risk technology.

It is for this reason that this Standard mandates that Spread Spectrum radios be used as a “last resort” when a narrowband licensed assignment is not available due to congestion, where there is a clear economic advantage in exploiting the potentially higher bandwidth of Spread Spectrum, and above all where there is an effective Spread Spectrum support group in place.

8.7 Basis of -75 dBm Design RSSI for Spread Spectrum

The basis of the Spread Spectrum design RSSI is similar to that of the Cellular RSCP. A field trial has shown that a lesser 10 dB fade margin is required, but that the frame threshold is likely to be correspondingly higher.

By comparison to Cellular, spread spectrum has a higher operating threshold. Cellular is able to operate with a worse SNR (ie as indicated by the negative Ec/Io) because it uses direct sequence modulation and much more sophisticated coding and error correction than the Spread Spectrum radios. Cellular also only has to contend with interference from other Cellular services whereas Spread Spectrum shares its operating band with all manner of users.

The field trial has shown that in the presence of urban noise + interference, the frame retry threshold is around -85 dBm. At this point frame throughput and latency of the Spread Spectrum link commences to degrade due to frame retries. The frame throughput decreases relatively slowly as the RSSI drops further below -85 dBm and some frames experience longer delay due to the retries.

As the RSSI is decreased to around -95 dBm the frame loss threshold is reached and frames begin to be lost due to retransmissions exceeding the set limit of five. At this point some frames experience latencies of up fivefold due to the retransmissions.

Below the frame loss threshold the SCADA protocol physical layer will experience increasing frame loss as the RSSI decreases and the SNR worsens. It is therefore advisable that the Spread Spectrum link RSSI remains above -95 dBm frame threshold to ensure that SCADA protocol physical layer frames are not discarded. The relationship between Spread Spectrum RSSI and throughput performance is depicted in Figure 4.

The -75 dBm design RSSI is arrived at by adding 10 dB for each of the site and fade margins as follows:

Design RSSI (dBm) = Frame Threshold (dBm) + Site Margin (dB) + Fade Margin (dB)

Field measurements have shown that the level of Spread Spectrum noise + interference in country towns is surprisingly commensurate with urban levels. Hence there is no differentiation between urban and country design RSSIs.

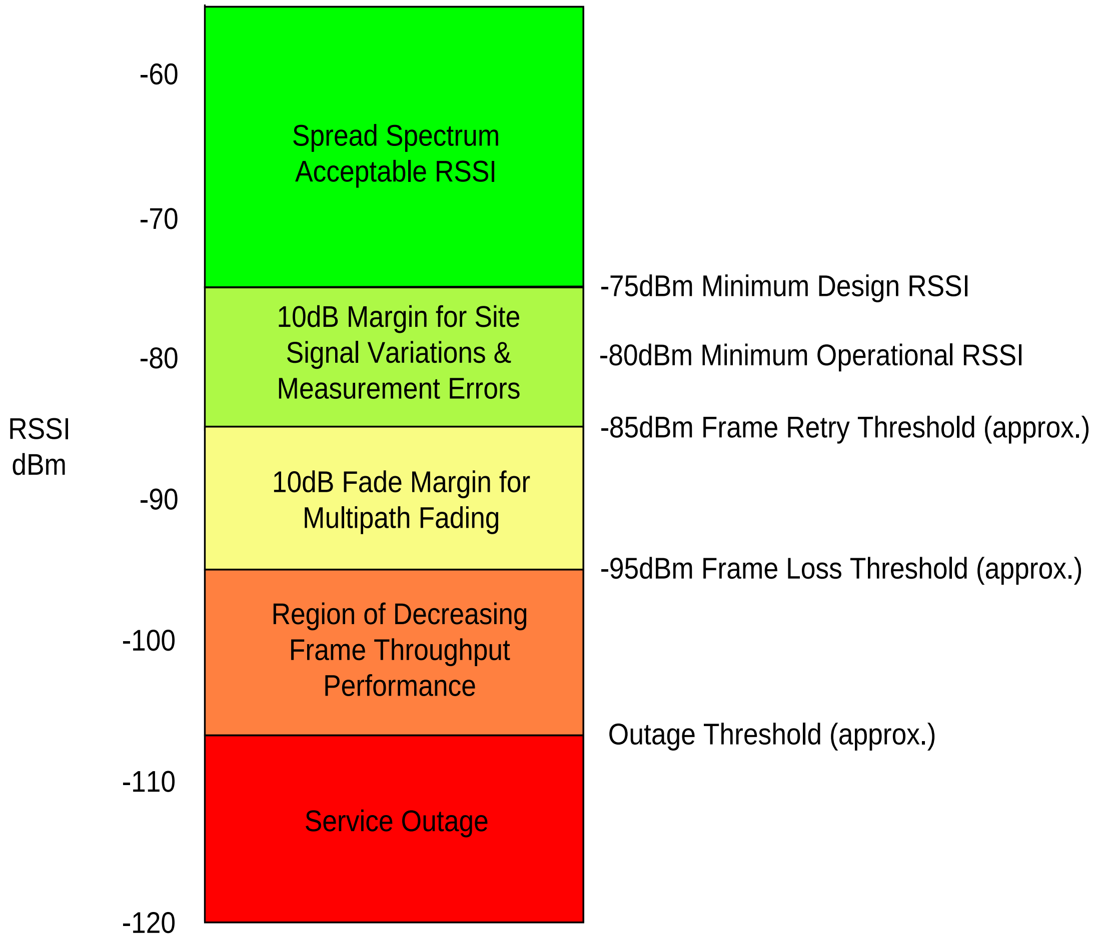


Figure 4 Relationship between Spread Spectrum RSSI and throughput performance.

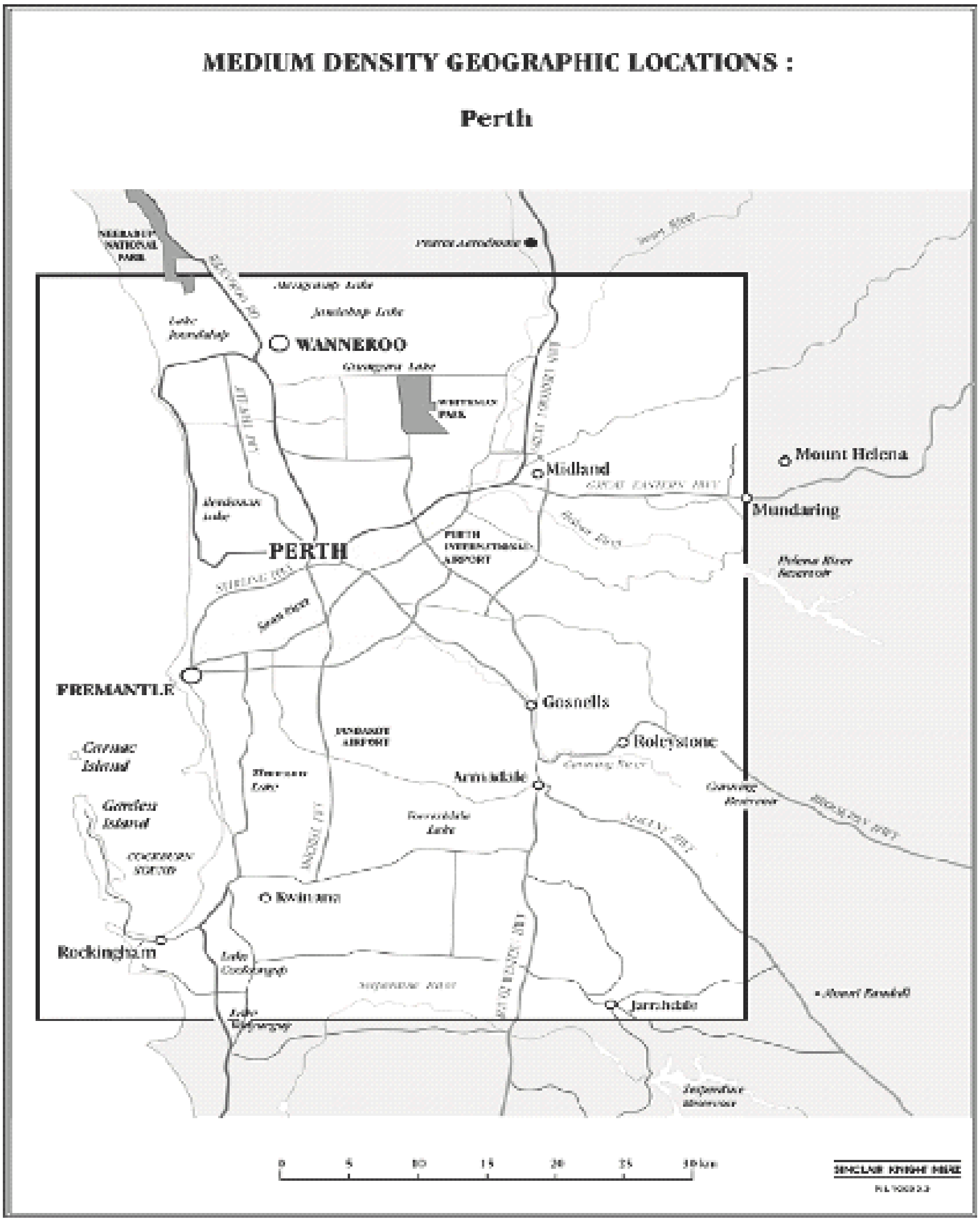
8.8 References

AS/NZS 4771 Technical characteristics and test conditions for data transmission equipment operating in the 900 MHz, 2.4 GHz and 5.8 GHz bands and using spread spectrum modulation techniques.

AS/NZS 4268 Radio equipment and systems - Short range devices - Limits and methods of measurement.

AS/NZS CISPR 11 Industrial scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – limits and methods of measurement.

9 Appendix E ACMA Medium Density Geographic Map



Coordinates

Point number	Zone	Easting	Northing
1	50	370000	6420000
2	50	370000	6490000
3	50	425000	6490000
4	50	425000	6420000

END OF DOCUMENT