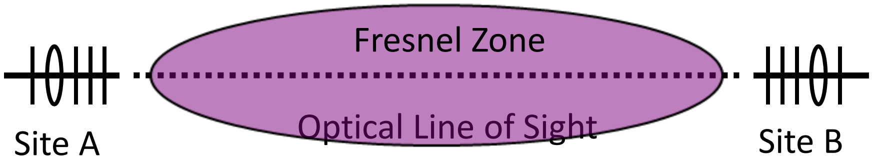
Choosing the right antenna

RF System Considerations

- Most problems associated with deployment of radio based telemetry systems are due to poor RF system design and installation errors.
- There are many factors to be considered when designing RF systems, but if basic guidelines are followed and expert assistance is used for doubtful paths and/or complex systems, then success is likely…
- For any radio based system to work, two primary considerations are:
  - 1) RF signal strength at the receiver.
    - All path losses and gains through the transmission system must be included in your assessment of this parameter.
  - 2) Line of sight (LOS) path
    - Both the transmitting and receiving antennas must be able to 'see' each other with adequate Fresnel Zone clearance. i.e. Not simply an 'optical line of sight'.



Fresnel Zone Calculator **Fresnel Zone Definition**

Determining Path Loss

- To determine path loss, transmitter output is first determined.
  - ➢ Transmitter output is boosted by system Antenna gain and reduced by transmission line and connector losses.
  - ➢ Effective Isotropic Radiated Power (EIRP) is given by:

    EIRP (dBm) = Tx Output (dBm) + Antenna Gain (dBi) - Cable and Connector Losses (dB)
- Then Free-Space loss over the length of the RF path is determined
  - ➢ Free-Space Loss of the signal occurs because electromagnetic waves tend to propagate and therefore disperse energy in all directions outward from their source. In what is known as the 'far-field', this loss is predictable, and given by:

    FSL (dB) = 32.45 + 20Log10F(MHz) + 20Log10D(km)
- Free-space loss is the single greatest source of RF system loss.
- The '6dB Rule'
  - ➢ The free-space path loss equation shows that each 6dB increase in EIRP equates to a doubling of range (distance). Conversely, a 6dB reduction in system losses (either by way of transmission line loss, either on receive or transmitter end) translates into a doubling of range.

[dBm vs. watt chart]
[Calculating Path loss]

dBm vs. Watt

Power Levels					
0.001	watt	1	milli-watts	0.0	dBm
0.002	watt	2	milli-watts	3.0	dBm
0.003	watt	3	milli-watts	4.8	dBm
0.004	watt	4	milli-watts	6.0	dBm
0.005	watt	5	milli-watts	7.0	dBm
0.006	watt	6	milli-watts	7.8	dBm
0.007	watt	7	milli-watts	8.5	dBm
0.008	watt	8	milli-watts	9.0	dBm
0.009	watt	9	milli-watts	9.5	dBm
0.010	watt	10	milli-watts	10.0	dBm
0.02	watt	20	milli-watts	13.0	dBm
0.03	watt	30	milli-watts	14.8	dBm
0.04	watt	40	milli-watts	16.0	dBm
0.05	watt	50	milli-watts	17.0	dBm
0.06	watt	60	milli-watts	17.8	dBm
0.07	watt	70	milli-watts	18.5	dBm
0.08	watt	80	milli-watts	19.0	dBm
0.09	watt	90	milli-watts	19.5	dBm
0.1	watt	100	milli-watts	20.0	dBm
0.2	watt	200	milli-watts	23.0	dBm
0.3	watt	300	milli-watts	24.8	dBm
0.4	watt	400	milli-watts	26.0	dBm
0.5	watt	500	milli-watts	27.0	dBm
0.6	watt	600	milli-watts	27.8	dBm
0.7	watt	700	milli-watts	28.5	dBm
0.8	watt	800	milli-watts	29.0	dBm
0.9	watt	900	milli-watts	29.5	dBm
1	watt	1,000	milli-watts	30.0	dBm
2	watt	2,000	milli-watts	33.0	dBm
3	watt	3,000	milli-watts	34.8	dBm
4	watt	4,000	milli-watts	36.0	dBm
5	watt	5,000	milli-watts	37.0	dBm
6	watt	6,000	milli-watts	37.8	dBm
7	watt	7,000	milli-watts	38.5	dBm
8	watt	8,000	milli-watts	39.0	dBm
9	watt	9,000	milli-watts	39.5	dBm
10	watt	10,000	milli-watts	40.0	dBm

Receiver Gain/Loss

- Having calculated transmitter output (EIRP) and Free-Space loss, the receiver gain/loss must now be determined.
  - Like transmitter output, receiver input is also boosted by system Antenna gain and reduced by transmission line and connector losses.
  - Receiver gain:

    Receiver Gain (dBm) = Antenna Gain (dBi) - Cable and Connector Losses (dB)
  - Receiver sensitivity determines the minimum receive level. This can be obtained from the manufacturers specifications.
    - This is typically around –106dBm

CABLE TYPE	*LOSS RELATIVE TO DISTANCE*							
	1 dB		*3 dB*		*6 dB*		*9 dB*	
	450Mhz	900Mhz	450Mhz	900Mhz	450Mhz	900Mhz	450Mhz	900Mhz
RG58C/U	2.3m	1.6m	7m	5m	14m	10m	20m	15m
RG223/U	3.1m	2.3m	9m	7m	18m	14m	28m	21m
RG213/U	6.1m	4m	18m	12m	37m	24m	55m	37m
Heliax LDF4-50A	19m	14m	57m	43m	114m	87m	171m	130m
Heliax LDF5-50A	38m	25m	114m	75m	229m	150m	343m	225m

Rule of thumb dBm losses for cable, connectors, arrester

1 db lose for every 25ft of LMR-400 cable N-N
.25 dB (approx.)per connector
.20 dB lightning suppressor (Polyphaser bulkhead part of our antenna kit)
.2db loss for the 3 ft of LMR-240 cable jumper cable SMA-N

Example; 1watt radio = 30dBm, FCC allows 36dBm
Antenna kit (YAGI-900-RDS-KIT) 20 ft LMR400 (-1 dBm approx), 3 ft LMR240 (-.2 dBm), 4 connectors .25 dBm ea. (-1 dBm), Polyphaser bulkhead connector (-.2 dBm) = -2.40 dBm

If you chose a 10 dBm gain Yagi, you would realize a 7+dBm gain and stay below the 36 dBm allowed limit.

Calculating Path loss

Calculating RF Path Loss

- The 'ideal RF Path' Loss = Tx Output – Free Space Loss + Rx Gain
- After path loss is determined it should be compared to the minimum receive level to determine the fade margin.
  - Fade margin is ideally at least 30dB greater than the minimum receive level (>20dB is considered good, <10dB is considered marginal)
- Example 1: 900MHz point to point system, YAGI antennas, 20km path
- Tx EIRP = Tx pwr 30dBm (1W) + 14dBi (15 el. YAGI) – 4dB (cable & connector losses) = 40dBm
- **Note: This exceeds the allowable 36dBm maximum EIRP!**
- **Recalculate using a lower gain antenna and/or less output power (e.g. 500mW = 27dBm)**
- Tx EIRP = Tx pwr 27dBm (500mW) + 11dBi (9 el. YAGI) – 4dB (cable & connector losses) = 34dBm
- Or = Tx pwr 24dBm (250mW) + 14dBi (15 el. YAGI) – 4dB (cable & connector losses) = 34dBm

- Free Space Loss = 32.45 + 20Log10 900(MHz) + 20Log10 20(km) = 117.55 dB
- Rx Gain = 14dBi (15 el. YAGI) – 4dB (cable & connector losses) = 10dB
- RF Path Loss = 34 dBm (Tx Output) – 117.55 dB (Free Space Loss) + 10 dB (Rx Gain) = -73.55 dBm
- Fade margin = 106 – 73.55 = 32.45

Path Loss Calculator

More than line of sight

More 'Ideal Path' Examples

Example 2: 900MHz point to point system, YAGI antennas, 50km path

Free Space Loss = 32.45 + 20Log10x900(MHz) + 20Log10 x50(km) = 125.5 dB

RF Path Loss = 34 dBm (Tx Output) – 125.5 dB (Free Space Loss) + 10 dB (Rx Gain) = -81.5 dBm

Fade margin = 106 – 81.5 = 24.5 dB

Example 3: Using 2.4GHz, 18dBi Grid Antenna with a 20km path

RF Path Loss = 30 dBm (Tx Output) – 126.07 dB (Free Space Loss) + 12 dB (Rx Gain) = -78.07 dBm

Fade margin = 106 – 78.07 = 27.93 dB

Example 4: Using 900MHz, 0dBi Whip Antenna with a 5km path

Tx EIRP = Tx pwr 30dBm (1W) + 0dBi (Whip) – 3dB (cable & connector losses) = 27dBm

RF Path Loss = 27 dBm (Tx Output) – 105.51 dB (Free Space Loss) –3 dB (Rx Loss) = - 78.51 dBm

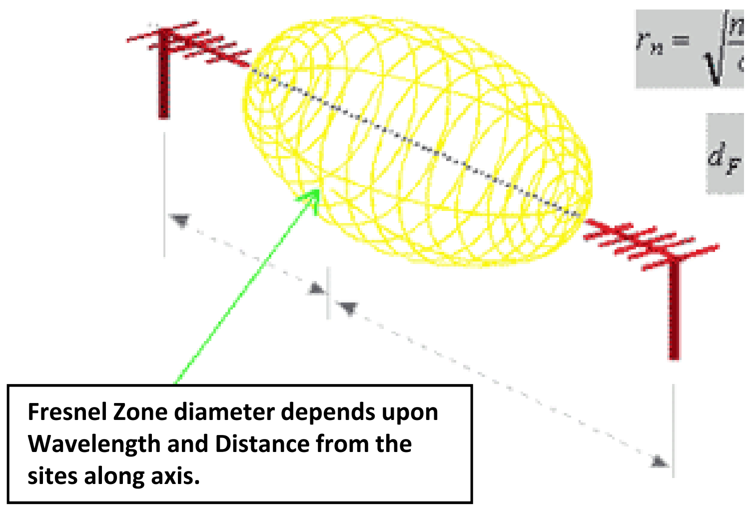
Fade margin = 106 – 78.51 = 27.49 dB

- The examples shown above all have acceptable fade margins and show that distances of 5-50km are easily achievable in ideal conditions, with appropriate RF power settings, antennas, cables and connectors.
- **What other considerations must we make?**

RF Path - Reality

- The ideal RF path calculations make no allowance for path obstructions, and should only be used where clear line of site can be established between the two antennas and adequate Fresnel zone clearance exists.
  - For obstructed paths, a profile of the earth contours will need to be drawn, with allowance for earth curvature and foliage to ensure path performance is adequate.
- The Path Profile is a profile view of a given point-to-point link.
  - Its primary function is to indicate the existence or otherwise of required Fresnel Zone clearance.

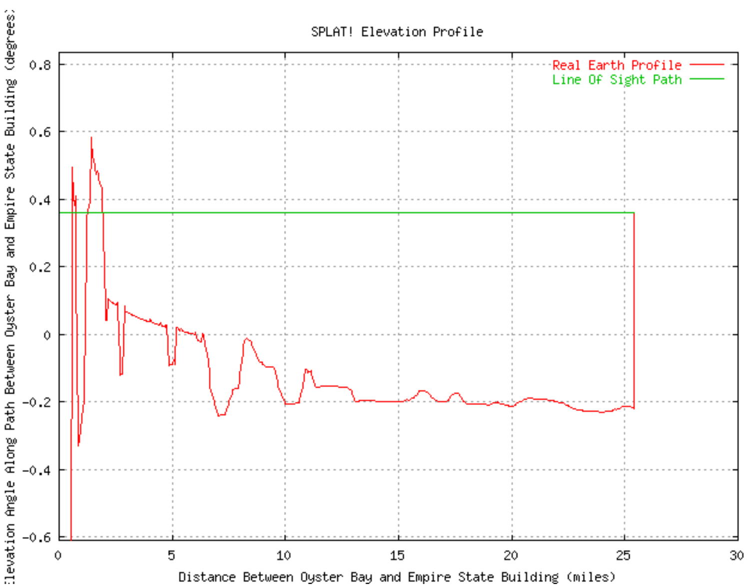
- **Antenna heights (AGL) are indicated as well as topographic details of the terrain (including known foliage conditions) between the sites.**
  - ➢ **In most RF system design, this is normally done using computer path analysis programs and the requisite terrain database.**
  - ➢ **The path profile analysis may also be done manually, using graph paper and topographic maps!**

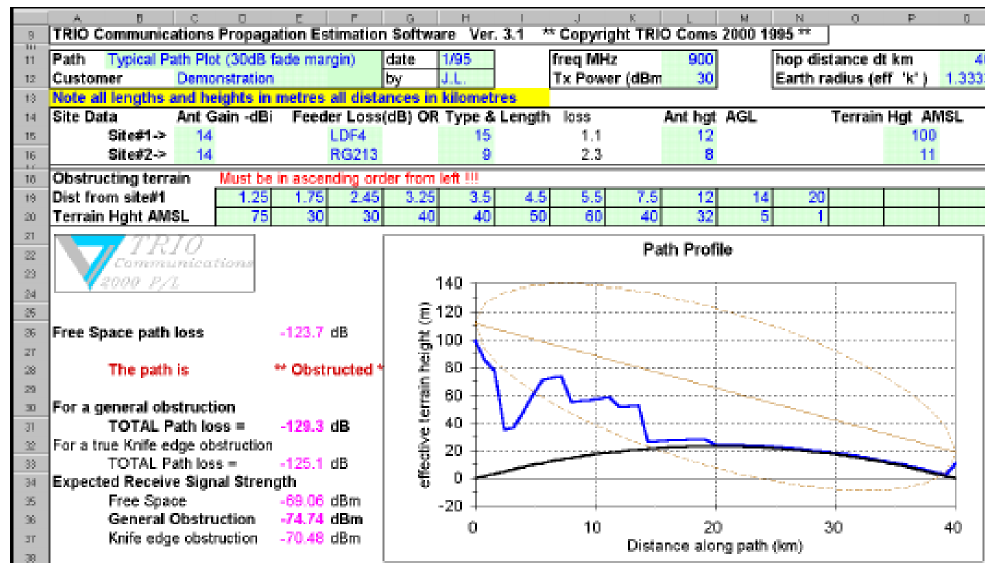


[Example of path study software]

RF Path - Analysis

- RF path analysis software is available to speed up the path profile process.
  - Most software includes a terrain database and requires entry of location co-ordinates, antenna height and transmitter power to produce a range of profile graphs and performance expectations.





http://www.pathloss.com/
http://pizon.org/rmw/install.html

Back to Freewave page

More products

Why Spread Spectrum?

Extracted from The *IEEE Spectrum* of August, 1990.

An article entitled *Spread Spectrum Goes Commercial,* summarized the coming of commercial spread spectrum:

Spread-spectrum radio communications, long a favorite technology of the military because it resists jamming and is hard for an enemy to intercept, is now on the verge of potentially explosive commercial development.

The reason: spread-spectrum signals, which are distributed over a wide range of frequencies and then collected onto their original frequency at the receiver, are so inconspicuous as to be 'transparent.' Just as they are unlikely to be intercepted by a military opponent, so are they unlikely to interfere with other signals intended for business and consumer users -- even ones transmitted on the same frequencies. Such an advantage opens up crowded frequency spectra to vastly expanded use.

Choosing an antenna **Radio accessories** **More products**

Spread Spectrum Operation

- In most countries, regulations allow for the *unlicensed* operation of spread spectrum radios.
- This has stimulated manufacturers to concentrate on research and development of sophisticated and affordable spread spectrum radios.
- Commercial unlicensed Spread Spectrum systems use the ISM (Industrial, Scientific and Medical) bands worldwide.
  - Frequencies used are:
    - 902 to 928 MHz
    - 2400 to 2483.5 MHz
    - 5725 to 5850 MHz
- Transmitter power output in the ISM band is limited to 1W (+30dBm).
- To minimize interference, Effective Isotropic Radiated Power (EIRP - power radiated by the antenna system), is limited to 4 W (+36dBm).

Country	900 MHz Allocation	2.4 GHz Allocation	5.8 GHZ Allocation	Comments
US, Canada, Group 1	902-928 (US) 902-928 (CAN) 902-907.2 (MEX) 922.8-928(MEX) HK: not allocated	2400-2483.5 MHz 2450-2483.5(MEX)	5725-5850 MHz 5725-5850 MHz 5725-5850 MHz 5725-5850 MHz	900 MHz band: Power restrictions in Mexico depending on usage area
Austria, UK, Group 2	Not allocated	2400-2483.6		
France	Not allocated	2446 - 2483.5		-20dBW/MHz limit
Spain	Not allocated	2445 - 2475		
Israel		2418 - 2475		stricter limits below 1 GHz
Korea		2400 - 2483.5	5725-5850 Mhz	special limits
Japan	Not allocated	2471 - 2497		special limits
Australia	915-928	2400 - 2483.5	5725-5825 MHz	1w: 2400-2445 MHz 200mW: above 2445
New Zealand	921-929	2400 - 2483.5	5725-5875 MHz	
Saudi Arabia		2413-2439		

<u>Group 1:</u> Argentina, Canada, Brazil, Chile, Columbia, Dominican Republic, Equador, Panama, Paraguay, Peru, Uruguay, Venezuela, Hong Kong, Indonesia, Mexico, Malaysia, Philippines, Singapore, South Africa, Taiwan, Thailand, Viet Nam

<u>Group 2</u>: Belgium, Czech Rep., Denmark, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg,Netherlands, Norway, Poland, Portugal, Slovenia, S. Africa, Sweden, Switzerland, Turkey, UK

Some of the Rules

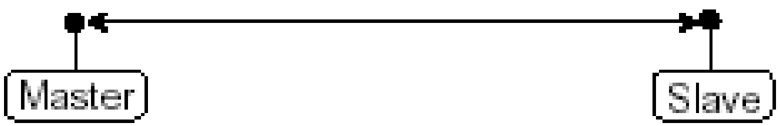
- There are rules and restrictions for spread spectrum use, that include output power, channel occupation periods, number of channels etc.
- Spread spectrum devices usually operate on a non-interference basis,
  - i.e. the device must be turned off if there is an interference situation

Parameter	**902-928 MHz**	**2400-2483.5 MHz**	**5725-5850 MHz**
Output power, peak	24 dBm for 25-50 hopping ch	30 dBm	30 dBm
EIRP, max	36 dBm	p2mp: 36 dBm	p2mp: 36 dBm
Note: 30dBm =1W, 36dBm = 4W		p2p: EIRP={30-(G-6)/3 + G}dBm	p2p: UNLIMITED
Number hopping ch.	≥ 25 for BW>250 kHz	≥ 75	≥ 75
Hopping channel separation	25 kHz or 20 dB W	25 kHz or 20 dB BW	25 kHz or 20 dB BW
Hopping channel 20 dB BW	maximum 500 kHz	maximum 1 MHz	maximum 1 MHz
	minimum 25 kHz	minimum 25 kHz	minimum 25 kHz
Hopping channel dwell time	≥ 50 hopping channels:l	0.4 sec/channel in 30 sec.	0.4 sec/channel in 30 sec.
	<0.4 sec/channel in 20 sec.		
	25-50 hopping channels		
	<0.4 sec/channel in 10 sec		
Processing gain, Direct Sequence	>10 dB	>10 dB	>10 dB
Processing gain, Hybrid FH/DS system	>17 dB	>17 dB	>17 dB
where p2p = pont to point and p2mp = point to multipoint			

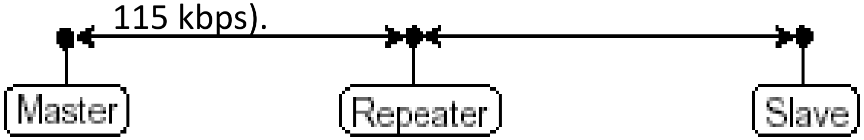
Choosing an antenna **Radio accessories** **More products**

Radio Network Setup

- The versatility of the radios allows data communication links to be established using a variety of different configurations. This makes it possible to extend the radios range and get around obstacles.
- A master communicating to a slave is the most common application.

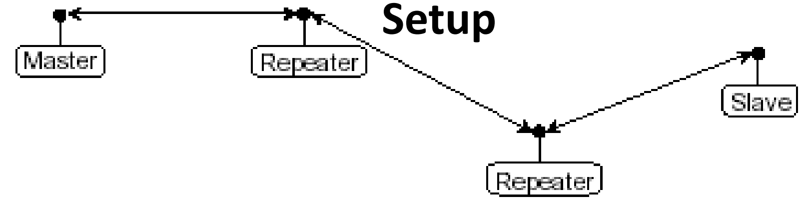


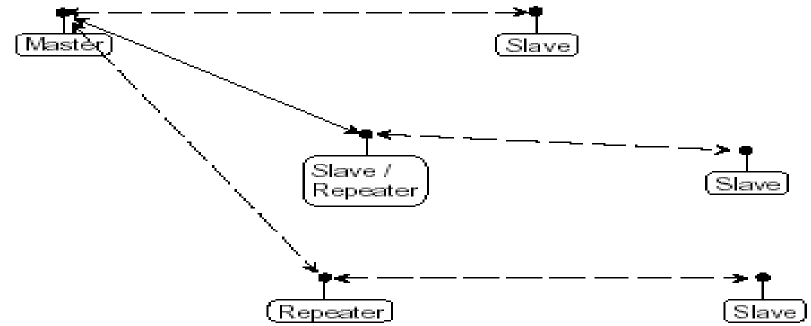
- Some applications require a repeater. The repeater may be sitting on a hilltop or other elevated structure to link the master to the slave.
    - When a repeater is used RF speed is reduced by half, making 115 kbps throughput unachievable (baud rate may still be set at 115 kbps).

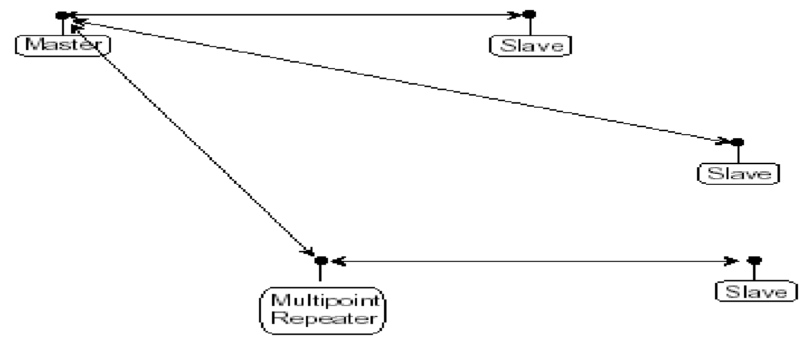


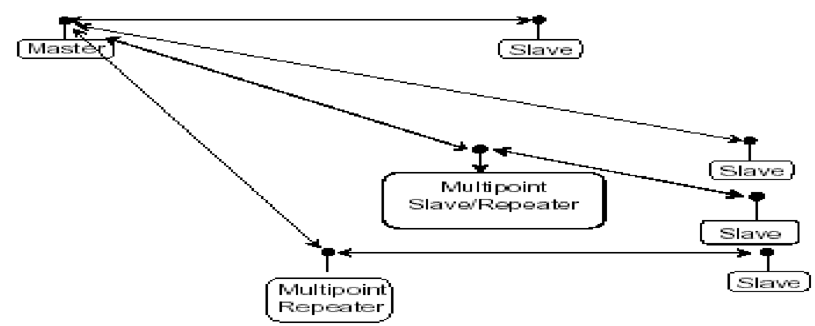
Wireless SCADAPack Specification

More Complex Network Setup





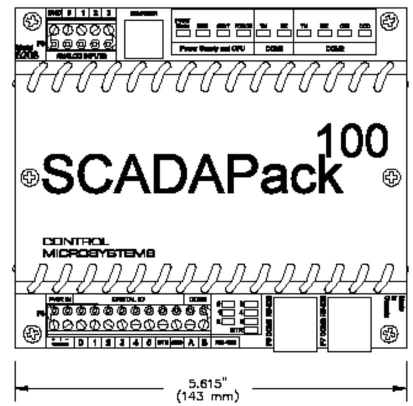


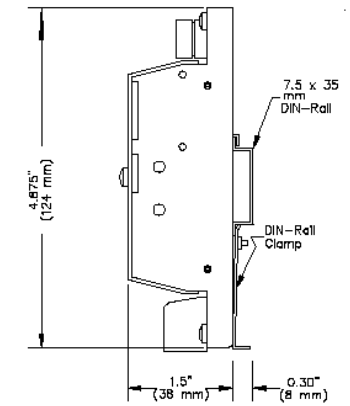


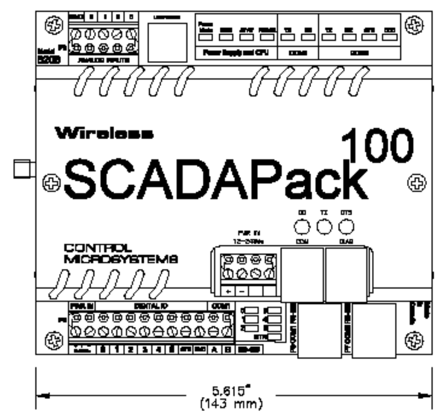
Back

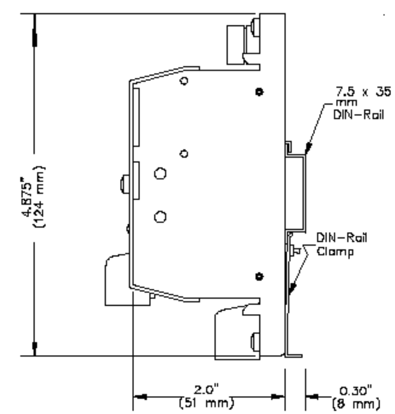
Integrated Radio

- The integrated radio solution is achieved without modification of the standard SCADAPack controller or I/O boards.
- The overall height is increased by 13mm to allow the radio to be mounted in the enclosure lid. The radio has its own LEDs, data port, diagnostic port and power connections.









Back