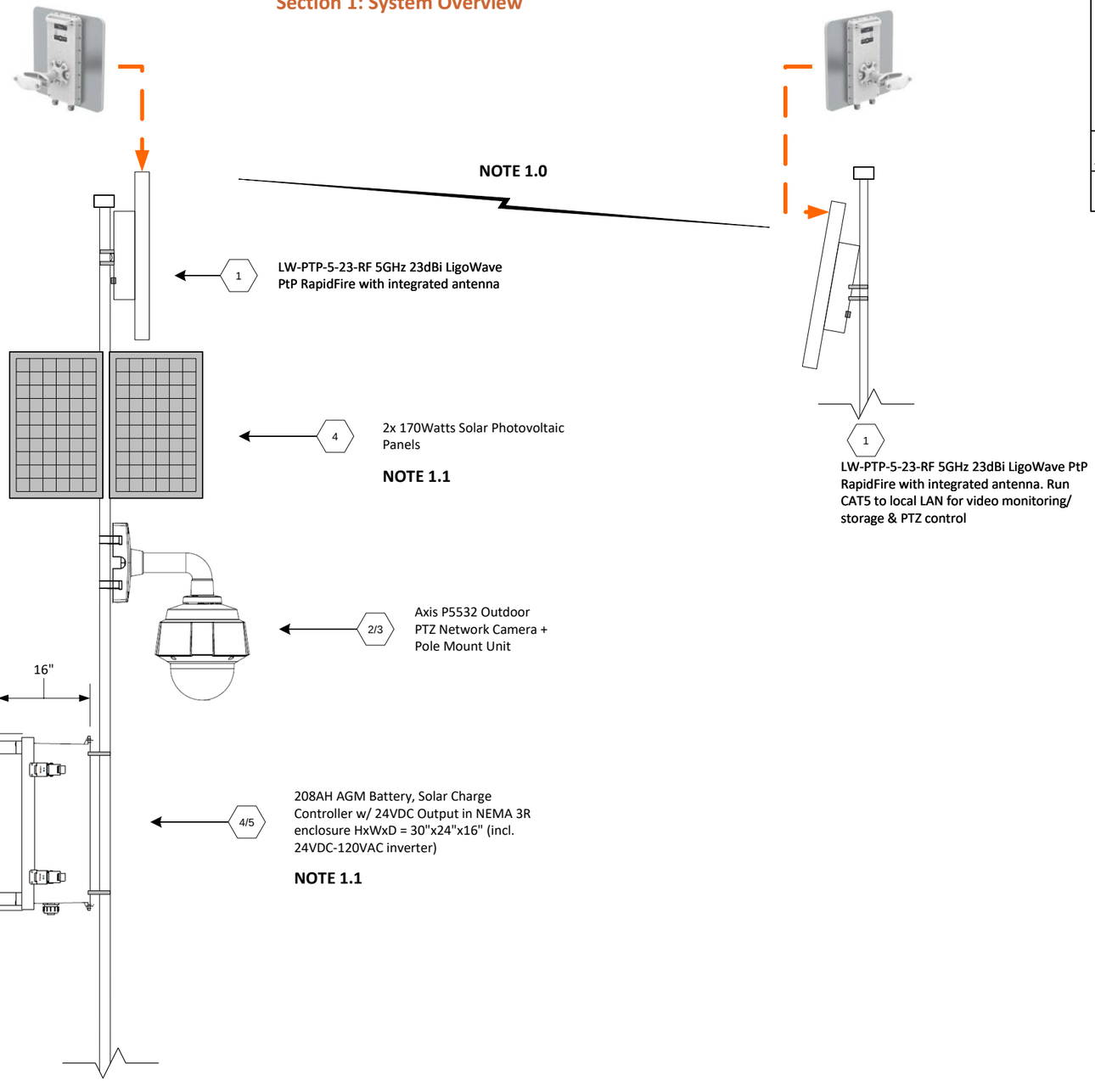
Section 1: System Overview



RfWel® Radio Frequency Wireless Electronics
116 N Roosevelt Ave Suite123
Chandler, AZ 85226 U.S.A
www.rfwel.com | 480.218.1877

Solar Powered Wireless Video Surveillance for Remote Site/ U.S.A

IP PTZ Camera, Unlicensed 5 GHz Wireless Backhaul, Solar PV Alternate Power
JOB # BWA-41875-1010
Section 1: System Overview

DRAWN BY: RT (Engr) APPROVED BY:	SIZE	LIC NO AZ ROC # 322820	DWG NO DWG-BW-418751010-002	REV 1A
FREQ(s): 5 GHz ISM	SCALE **NO SCALE**	FRN: 0018086041	SHEET 1 OF 5	

Bill of Materials

ITEM	QTY.	RFWEL SKU	DESCRIPTION
1	2	LW-PTP-5-23-RF	LW-PTP-5-23-RF 5GHz 23dBi LigoWave PtP RapidFire
2	1	PTZ Camera	IP PTZ Camera
3	1	RPSTL12/24M-200-170	Pre-Packaged 170W, 208AH, 12/24VDC POE Solar System
4	1	PST-30S-24A	300W 24VDC-120VAC Pure Sine Wave Inverter

NOTES:

1.0 See Page-2 on RF link budget analysis and wireless link assumptions.

1.1 See Page-5 on solar module sizing including load estimates & usage duty-cycle assumptions.

1.2 System designed for wireless video backhaul into a command & control center 0.5miles from camera installation location. Could be easily extended to several miles or replaced with alternative wireless backhaul methods such as 4G LTE or 5G NR. Contact an Rfwel wireless support tech to discuss any required modifications.

Section 2: 5 GHz Point-to-Point Radio RF Link Analysis (Various data rates with diferent channel selection)

20MHz Channel					
Modulation	RX Level	Fade Margin	Link availability due to rain	TX/RX	Max Throughput
BPSK 1/2	-43.97 dBm	52 dB	N/A	1x1	6 Mbps
QPSK 1/2	-43.97 dBm	49 dB	N/A	1x1	12 Mbps
QPSK 3/4	-43.97 dBm	47 dB	N/A	1x1	18 Mbps
16-QAM 1/2	-43.97 dBm	41 dB	N/A	1x1	23 Mbps
16-QAM 3/4	-43.97 dBm	39 dB	N/A	1x1	33 Mbps
64-QAM 2/3	-44.97 dBm	34 dB	N/A	1x1	47 Mbps
64-QAM 3/4	-45.97 dBm	32 dB	N/A	1x1	52 Mbps
64-QAM 5/6	-47.97 dBm	28 dB	N/A	1x1	57 Mbps
256-QAM 3/4	-48.97 dBm	23 dB	N/A	1x1	71 Mbps
BPSK 1/2	-43.97 dBm	52 dB	N/A	2x2	13 Mbps
QPSK 1/2	-43.97 dBm	49 dB	N/A	2x2	25 Mbps
QPSK 3/4	-43.97 dBm	47 dB	N/A	2x2	36 Mbps
16-QAM 1/2	-43.97 dBm	41 dB	N/A	2x2	47 Mbps
16-QAM 3/4	-43.97 dBm	39 dB	N/A	2x2	66 Mbps
64-QAM 2/3	-44.97 dBm	34 dB	N/A	2x2	95 Mbps
64-QAM 3/4	-45.97 dBm	32 dB	N/A	2x2	105 Mbps
64-QAM 5/6	-47.97 dBm	28 dB	N/A	2x2	115 Mbps
256-QAM 3/4	-48.97 dBm	23 dB	N/A	2x2	143 Mbps

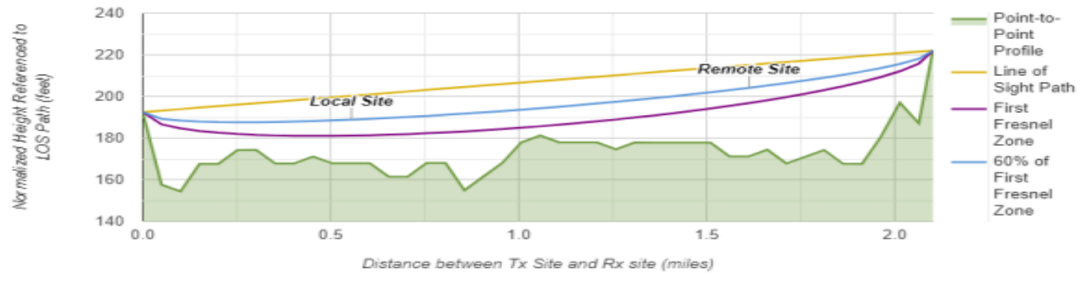
80MHz Channel					
Modulation	RX Level	Fade Margin	Link availability due to rain	TX/RX	Max Throughput
BPSK 1/2	-43.97 dBm	47 dB	N/A	1x1	24 Mbps
QPSK 1/2	-43.97 dBm	44 dB	N/A	1x1	55 Mbps
QPSK 3/4	-43.97 dBm	41 dB	N/A	1x1	81 Mbps
16-QAM 1/2	-44.97 dBm	36 dB	N/A	1x1	105 Mbps
16-QAM 3/4	-44.97 dBm	33 dB	N/A	1x1	158 Mbps
64-QAM 2/3	-45.97 dBm	28 dB	N/A	1x1	215 Mbps
64-QAM 3/4	-46.97 dBm	25 dB	N/A	1x1	241 Mbps
64-QAM 5/6	-47.97 dBm	22 dB	N/A	1x1	268 Mbps
256-QAM 3/4	-48.97 dBm	17 dB	N/A	1x1	320 Mbps
256-QAM 5/6	-49.97 dBm	14 dB	N/A	1x1	350 Mbps
BPSK 1/2	-43.97 dBm	45 dB	N/A	2x2	48 Mbps
QPSK 1/2	-43.97 dBm	42 dB	N/A	2x2	110 Mbps
QPSK 3/4	-43.97 dBm	40 dB	N/A	2x2	162 Mbps
16-QAM 1/2	-44.97 dBm	36 dB	N/A	2x2	210 Mbps
16-QAM 3/4	-44.97 dBm	33 dB	N/A	2x2	315 Mbps
64-QAM 2/3	-45.97 dBm	28 dB	N/A	2x2	430 Mbps
64-QAM 3/4	-46.97 dBm	25 dB	N/A	2x2	482 Mbps
64-QAM 5/6	-47.97 dBm	22 dB	N/A	2x2	535 Mbps
256-QAM 3/4	-47.97 dBm	16 dB	N/A	2x2	640 Mbps
256-QAM 5/6	-49.97 dBm	12 dB	N/A	2x2	700 Mbps

Rfwel Link Analysis Report

Date Generated: 12/4/2021 4:28 AM EST

Site Information			
TX Site Name	Local Site	RX Site Name	Remote Site
Radio Type	LigoPTP 5-23 RapidFire	Radio Type	LigoPTP 5-23 RapidFire
Latitude	30.053	Latitude	30.044
Longitude	-95.585	Longitude	-95.619
TX Power	28.0 dBm	RX Threshold	-96.0 dBm
Ant. Gain	23.0 dBi	Ant. Gain	23.0 dBi
Ant. Height	35.0 feet	Ant. Height	35.0 feet
Parameters			
Frequency	5800.0 MHz	Climate	Maritime Subtropical
Ant. Polarization	Vertical	Measurement System	Imperial System
Misc. Loss	0.0 dBm	Rain Rate	0.0 mm/hr
Results			
Total Path Loss	118 dB	Thermal Fade Margin	52 dB
RX Signal Level	-43.969 dBm	Distance between sites	2.101 miles
EIRP	51.0 dBm	Link availability due to rain	N/A

Path profile between TX and RX sites



RfWel®
Radio Frequency Wireless Electronics

116 N Roosevelt Ave Suite123
Chandler, AZ 85226 U.S.A
www.rfwel.com | 480.218.1877

Solar Powered Wireless Video Surveillance for Remote Site/ U.S.A

IP PTZ Camera, Unlicensed 5 GHz Wireless Backhaul, Solar PV Alternate Power
JOB # BWA-41875-1010
Section 2: 5 GHz RF Radio Link Analysis & Specifications

DRAWN BY: RT (Engr) APPROVED BY:	SIZE	LIC NO AZ ROC # 322820	DWG NO DWG-BW-418751010-002	REV 1A
FREQ(s): 5 GHz ISM	SCALE **NO SCALE**	FRN: 0018086041	SHEET 2 OF 5	

NOTES:

2.0 Results of link analysis shows that we meet this 2 mile link with 52dB fade margin (typical fade margin of >10dB required to account for interference power, environmental conditions, orientation imperfections etc).

2.1 System designed for 2 mile line-of-sight (LOS) links. Not compatible with full Non-line-of-sight (NLOS) links. For nLOS the expected obstructions would be light foliage and/or partial Fresnel zone obstruction but with significant reduction in distance.

2.2 LigoWave PtP radios capable of range of several miles depending on desired throughput and number/nature of obstructions present in the line-of-sight. Shown here with 23dBi integrated panel antennas. To increase link range you would need:

i) Replace the model with 23dBi integrated antennas with system with external antenna ports such that external antennas may be installed to meet specific site needs e.g co-location interference suppression, improved coverage radius, improved range with higher antenna gain etc.

2.3 Selected LigoWave radios designed for Point-to-point (PtP) links. To expand the system to include multiple sensor or client nodes monitored/controlled from the same command center or NOC you would need to:

i) Replace Base-station radio to a PtMP radio (Most LigoWave PtPs can also be configured to be PtMPs).

ii) Use omni-directional or sector antenna at base-station to provide appropriate beamwidth pattern to the nodes.

Section 3: Outdoor Rugged Network PTZ Camera Specification & Possible Configuration Settings for Designed Backhaul Bandwidth

Name	Model	No. of cams	Bandwidth (View, Rec, Event)	Storage (8 days)
1 Remote Wireless Video	AXIS P5532 (60Hz)	1	3.0 Mbit/s, 1.4 Mbit/s, 862.5 Kbit/s	178.3 GB

Client Hardware Recommendation

Server
Dual Core 2.0GHz CPU,
1GB RAM,
100Mbit Network Card,
1 HDDs providing at least 214.0 GB storage,
Windows XP professional, Vista Business or Windows 7 professional or higher (32/64bit)

Client
Dual Core 2.0GHz CPU,
1GB RAM,
100Mbit Network Card,
Graphics card with full DirectX 9.0 and 256MB onboard memory,
Professional monitor with resolution 1280x800 or higher,
Windows XP professional, Vista Business or Windows 7 professional or higher (32/64bit)

License Recommendation US

License	qty.
4-base license *Part: 0202-054*	1

Camera

Name	Image scenario	Audio	Model	No. of channels
Remote Wireless Video	Station	☐	AXIS P5532 (60Hz)	1

Viewing

Frame rate	Resolution	Compression type	Compression	Bandwidth
6 fps	704x480 4CIF	MotionJPEG	10	3158 Kbit/s

Continuous recording

Record for	Frame rate	Resolution	Compression type	Compression	Bandwidth
24 h	6 fps	704x480 4CIF	MotionJPEG	70	1447 Kbit/s

Event recording

Alarm	Frame rate	Resolution	Compression type	Compression	Bandwidth
10 %	30 fps	704x480 4CIF	MotionJPEG	50	8625 Kbit/s

RfWel® Radio Frequency Wireless Electronics
116 N Roosevelt Ave Suite123
Chandler, AZ 85226 U.S.A
www.rfwel.com | 480.218.1877

Solar Powered Wireless Video Surveillance for Remote Site/ U.S.A

IP PTZ Camera, Unlicensed 5 GHz Wireless Backhaul, Solar PV Alternate Power
JOB # BWA-41875-1010
Section 3: Video Specifications

DRAWN BY: RT (Engr)	SIZE	LIC NO	DWG NO	REV
APPROVED BY:		AZ ROC # 322820	DWG-BW-418751010-002	1A
FREQ(s): 5 GHz ISM	SCALE NO SCALE	FRN: 0018086041	SHEET 3 OF 5	

NOTES:

3.0 Configuration settings for video quality can be changed depending on the backhaul you are using i.e. PtP system or Cellular(4G LTE/5G NR).

For example, if backhaul has lower bandwith:
i) change viewing resolution to 352x240 CIF for 1.253Mbps
ii) Leave resolution as 704x768 4CIF and change compression to H.264 for 980kbps

3.1 Camera includes software license for viewing/recording/control from one remote station. For multiple station support additional licenses required.

Section 4: Solar Sizing & Load Estimates

4.0 Solar system sized for the following requirements: "… will need power for daytime use and enough to power the camera and other equipment when the weather doesn't cooperate. This is not a high security or mission critical installation, so the camera doesn't have to be up all the time, but uptime needs to be reasonable …"

4.1 Usage window estimated at approximately 0700h-1800h daily with a 100% usage duty cycle in that window. Battery capacity sized to power loads during this window without any recharge from solar panels and for 80% battery discharge limits when no solar during that window.

4.2 LOADS:

- LW-PTP-5-23-RF 5GHz LigoWave PtP: POE 42 - 57VDC, 8.6W typical, 20W max (we use double the typical power for our calculations)
- *Axis P5532 PTZ Camera: POE- 55VDC, 30W max*
(we use worst case max power value for our calculations)
- *Samlex 24VDC-120VAC Inverter: 85% peak efficiency, <400 mA idle current.*
(we use a 75% efficiency estimate)

Load1 (radio) =~ 220 WH/day, 10 AH/day
Load2 (camera) =~ 413 WH/day, 18 AH/day

4.3 Min Solar insolation (Sun-Hours per day) for Chandler, AZ (Rfwel's HQ) per DOE is 5.78 Hrs/day. See Page-5 for more information Regional Peak Sun Hours in the U.S.A.

4.4 SOLAR ARRAY SIZING:

- Effective AH/day required to power loads = 34 AH/day (20% loss from battery charge/discharge)
- Total solar array amps reqd = 34/5.78 A = 5.9 A
  * note we use worst case minimum solar insolation value to allow for system margin
- Our setup has 2 panels rated at 170W and a nominal voltage of 12VDC to give 7.1A;
- since we need 24VDC to charge our battery string we wire the panels in series to give 24VDC.

4.5 BATTERY CAPACITY SIZING:

- As before effective AH/day required to power loads = 34 AH/day
- We provide for 2-days with no solar and percent of time during duty-cycle window when there will be no solar to power battery estimated at 100% (i.e can have 2 full day without solar) = 2*34 = 68 AH
- Retain a 20% reserve after deep discharge – min capacity = 68AH/0.8 = 85AH
- Since we use nominal 12VDC batteries we need to arrange 2 batteries in series to yield 24VDC system voltage.

→ We select 4 x 12V 52AH gel battery; they are connected as two pairs with a pair connected in series and the pairs connnected in parallel to each other to generate 24VDC battery bank output voltage (extra capacity used for idle mode leakage current & to protect against variations in solar insolation)

(The following SKU meets these demands RPSTL12/24M-200-170)

RfWel® Radio Frequency Wireless Electronics
116 N Roosevelt Ave Suite123
Chandler, AZ 85226 U.S.A
www.rfwel.com | 480.218.1877

Solar Powered Wireless Video Surveillance for Remote Site/ U.S.A

IP PTZ Camera, Unlicensed 5 GHz Wireless Backhaul, Solar PV Alternate Power
JOB # BWA-41875-1010
Section 4: Solar Sizing Details

DRAWN BY: RT (Engr) APPROVED BY:	SIZE	LIC NO AZ ROC # 322820	DWG NO DWG-BW-418751010-002	REV 1A
FREQ(s): 5 GHz ISM	SCALE **NO SCALE**	FRN: 0018086041	SHEET 4 OF 5	

NOTES:

4.6 To increase amount of load support e.g for increased usage duty cycle or night use, for increased radio throughput/range/transmit-power, to accommodate devices added to the system, to support increased number of no-sun-days or no-sun-hours per day, for increased pan, tilt & optical zoom mechanical activity or to account for environmental conditions that lead to increased use of heater/blower:

i) Increase the number of solar array modules in parallel with existing string. E.g Two more series mounted modules in parallel with existing two will give a total module output current of about 14A. Existing system includes a 30A solar-charge controller so can handle up to 4 parallel strings (or 8 modules) which should comfortably give 24hr use with excess capacity margin) [Order SKU=RPL12/24M-200-340 which includes 2 170 Watt modules & side-of-pole mount respectively]

ii) Add 4 additional 12V, 52 AH batteries and wire the series-combination of these batteries in parallel to existing battery bank. Batteries are Lead Acid AGM.

4.7 NOTE one should not add batteries without adding solar module(s) unless the load is reduced since there would otherwise be little to no residual current to charge increased battery capacity during sun-day duration. In fact notice current system at max loads provides a slow rate of battery recharge so if non-sun-days/hrs are anticipated to exceed estimates, additional solar pv modules strongly recommended.

4.8 The 24VDC-120VAC inverter used to power the AXISP5532 High Power 802.3at POE includes a low-voltage disconnect setting when battery bank output voltage goes below 20V (and a reconnect when it goes back to 23V). This prevents camera from draining battery completely which would affect useful battery life.

4.9 If system usage activity or load as detailed in 1.6 is increased or not carefully controlled outside spec'd usage window and to accommodate the idle PTP radio power (with no transmit/receive activity) and inverter idle leakage power after camera disconnect consider additional LVD circuit at output of battery bank [Order SKU=LVD24-50-NM 24V Variable Low Voltage Disconnect]

RfWel®
Radio Frequency Wireless Electronics
116 N Roosevelt Ave,Suite123
Chandler, AZ 85226, U.S.A
www.rfwel.com | 480.218.1877

Solar Powered Wireless Video Surveillance for Remote Site/ U.S.A

IP PTZ Camera, Unlicensed 5 GHz Wireless Backhaul, Solar PV Alternate Power
JOB # BWA-41875-1010
Section 5: Solar Sizing Details

DRAWN BY: RT (Engr) APPROVED BY:	SIZE	LIC NO AZ ROC # 322820	DWG NO DWG-BW-418751010-002	REV 1A
FREQ(s): 5 GHz ISM	SCALE **NO SCALE**	FRN: 0018086041	SHEET 5 OF 5	

Section 5: Solar Sizing & Load Estimates

5.0 The graphs and images below highlight the total insolation/ peak sun hours received across different parts of the U.S.A with data obtained from the NREL. The PSH (Peak S un Hour) is that time of the day when the intensity of the solar radiation reaches 1kW/m^2 over a period of 1 hour; it is an ideal measure.

5.1 When the Irradiance on the panel is at its max. a 250W panel will ideally output 250W ignoring resistance and temperature losses. In our example if we take the PSH for Chandler, AZ to be 5.78 hours will have a total daily solar output of 1445Wh.