PORTABLE POWER FOR AMATEUR RADIO

PART 1: HOW MUCH DO YOU NEED?

DAVE WILKIE – K6EV

Hey, I didn't ask how much you WANTED.
How much power do you need?

PART 1 OF A SERIES:

1. **<u>TODAY</u>**: How much power do you need for YOUR operating conditions?
   - Include first version of a calculator to make the math easy.

<u>In the future:</u>

2. Types of storage batteries – pros and cons – some examples.

3. Solar panels and solar controllers – sun hours – effect on battery size.

4. Small generators; small inverters

SAFETY – DON'T "ASSUME"

- High currents from large batteries can be very dangerous. 12V isn't 'safe'.
- Shorts can cause battery explosions and fires. Watches, rings, wires, TOOLS..
- Electrocution from 120/220V: Generators etc.
- Watch out for generators + rain.
- Protect batteries from physical damage. Don't use damaged batteries.
- Pay attention to the warnings and ask a professional electrician if in doubt.
- If serious injury and death isn't enough, consider the equipment damage!
- Use these notes at your own risk! Follow manufacturer's guidance.

WHAT IS THE OPERATING GOAL AND SETTING?

FINDING A SOLUTION REQUIRES DEFINING THE PROBLEM:

- **How/where/when will you operate?** 4-6 hours of casual activity at the park is very different from a 24 hour intense Field Day commitment. Is unlimited AC power available? How long is the event? How intensely will you really operate?
- **Modulation and Power Level:** SSB, CW, FT8 and FM can have substantially different average power consumption. How much power output will you request of your transceiver?
- **Know Your Equipment Specs:** Is the gear matched to the operating plan?
- **Don't ignore power consumption during receive:** You spend a lot of time listening and it's a significant factor in portable radio efficiency.

SEVEN AREAS AFFECTING ENERGY DEMAND:

Let's define the operating plan well enough to quantify these key inputs:

Then we will use a calculator to determine the total Amp-hours of capacity needed.

1. What is the selected transmitter power level?
2. What are the power consumption specs for the radio to be used?
3. What modulation? CW, SSB, FM vs. DIGITAL. Big effect on power drain.
4. How long is the operating event, including rest and breaks?
5. What percentage of the event time is 'radio-active' time?
6. During 'radio-active' time, what % of time is TX, RX or STANDBY?
7. Are there other loads on the power source (accessories)? Estimate those.

If you will operate in more than one configuration, different radios, etc. then it is suggested that you model each one individually and sum the total demand for each.

1. TRANSMIT POWER LEVEL

- Higher power = Faster power drain AND higher peak demand.
  - Only applies during 'transmit time'. Varies somewhat by radio model and settings.
  - Example: 100W HF Transceiver – Estimated DC supply current in Amps at 13.8V for Key-Down CW or FM or DIGITAL/FT8 at a power level of:
    - 100 Watts PEP: 20 Amps to 24 Amps
    - 50 Watts PEP: about 11.5 to 13.5 Amps
    - 5 Watts PEP: about 5 to 7 Amps

Note: Radio efficiency converting DC power to RF power: For 100W of RF output a typical radio may consume roughly 20A of DC power at 13.8V. That's 276 Watts of DC power, for a **conversion efficiency of about 36%.** If you run the radio from a 120VAC switching power supply there will be additional losses in efficiency. Clearly a 100W radio uses a lot more than 100W. You also use extra power if you have to convert from a DC voltage other than 13.8V.

Note: Specs vs reality: The IC-7300 spec is 21 Amps. QST's lab reported 18.5A. FT-991/FT-991A spec is 23 Amps; QST's lab reported 19.6A for non-A version. Other 'typical' operating tests have reported slightly lower currents for each. Various online sources report receive currents of under 1A for the 7300 and just under 2A for the 991 – both below the manufacturer's specs. Similarly, your ACTUAL operations will deviate from what you model. So **consider some extra operating margin**, depending on the importance of the event.

2. RADIO SPECS - EXAMPLES: IC-7300 AND FT991A

IC-7300 Manufacturer's Specs. (Typical probably a little lower).

- Power consumption:

Receive	Standby	0.9 A
	Maximum audio	1.25 A
Transmit	Maximum power	21.0 A

NOTE: 'Standby' practically applies only to squelched FM mode. Per our assumptions.

FT-991A Manufacturer's Specs. (Typical probably a little lower).

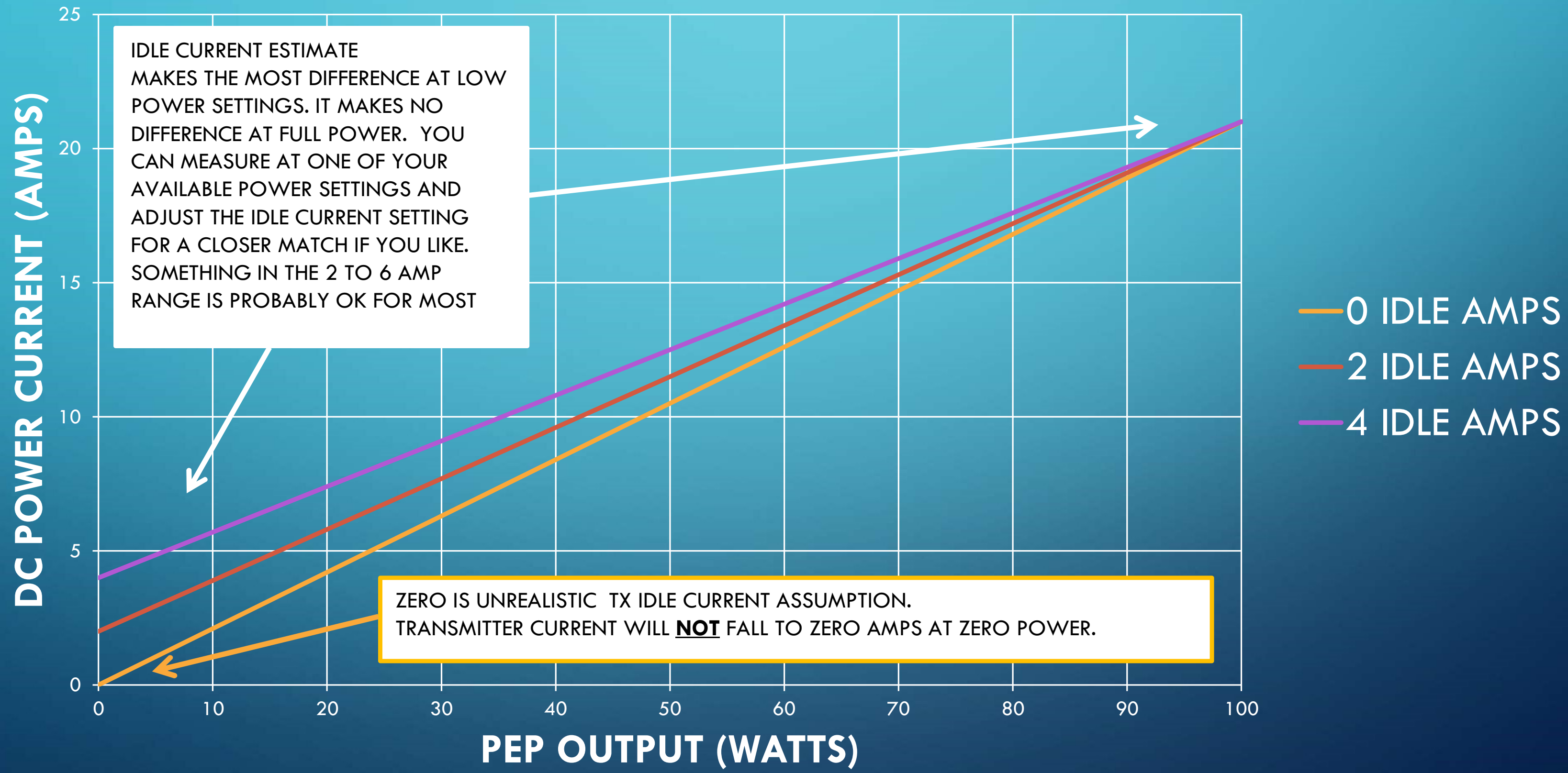
Rx (no signal)	1.8 A
Rx (signal present)	2.2 A
Tx	23 A (HF/50 MHz 100 W), 15 A (144/430 MHz 50 W)

NOTE: 'Rx (no signal) = 'Standby' practically applies only to squelched FM mode. Per our assumptions.

Manufacturer's don't usually specify DC current draw during TX at minimum power. It is NOT zero – LOTS of power gets used during TX running circuits other than the final amplifier. Ignoring this will greatly under-estimate DC power drain at reduced RF power, whether due to modulation or power setting. As Examples: '0' power TX current draw for the IC-7300 ~ 5A, FT991A ~ 6A, ID-5100 ~2.5A and an HT around 0.5A. **Our calculator allows us to enter a measured or estimated theoretical value @ 0W.**

2.1 MORE ON TX IDLE/BIAS CURRENT – AFFECTS POWER DEMAND AT REDUCED % OF FULL POWER

PEP POWER VS DC AMPS FOR VARIOUS ESTIM. IDLE AMPS



3. MODULATION TYPE –> 'DUTY FACTOR'

DUTY FACTOR = AVERAGE % OF SELECTED PEP DURING TRANSMIT.

- For FM or for most DIGITAL: Average Power = selected PEP. Duty Factor = 100%.
- For CW, average key-down % while sending is 44% or less. Duty Factor = 44%.
- For SSB, Average power varies with your voice, mic gain, compression, density of speech, etc. Probably is below 20% of PEP for typical radio settings. Duty Factor = 20%.

  The most aggressive contest station/operator will not exceed 40%. It may be below 10% for casual chat and relaxed compression settings. Results WILL vary. Calculator default is 20% for SSB.

WHAT IS THE EFFECT OF THIS?

- **Your IC-7300 set for 100W PEP may use an AVERAGE of 18-21 Amps FT8 or FM, probably about 11-14 Amps transmitting CW, and 8-10 Amps for SSB, including allowance for current that flows in the transmitter even at zero watts output.**

3.1 MORSE DUTY FACTOR = 44% (LESS IF SLOWED VIA FARNSWORTH METHOD)

Standard Morse Timing Ratios at ANY WPM (Assumes no 'Farnsworth' slowing of WPM)

- Dit=1 time unit
- Dah=3 units
- Space between dits or dahs = 1 unit each
- Space between complete letters = 3 units each
- Space between complete words = 7 units each

"PARIS" Standard = . _ _ .   . _   . _ .   . .   . . .   + one word-space

- 10 dits = 10 units
- 4 dahs = 12 units
- 9 spaces between dits/dahs = 9 units
- 4 spaces between letters = 12 units
- 1 space at end of word = 7 units

Total of 50 units: 10 + 12 = 22 are dit/dah key down time = 44% duty factor.

The transmitter is essentially at 0 watts except during the 44% key-down time. We use 44% though many calculators assume 40% or less.

Depending on transmitter design and break-in settings, the TX DC idle power MIGHT be lower for CW than other modes. If you measure a lower value you can substitute a lower zero power current for CW. We ignored this in the sample results provided later as it affects a fraction of TX time which is a fraction of operating time.

3.2 SSB VOICE – 20%? SSB DIGITAL 100%?

---100%

---0%

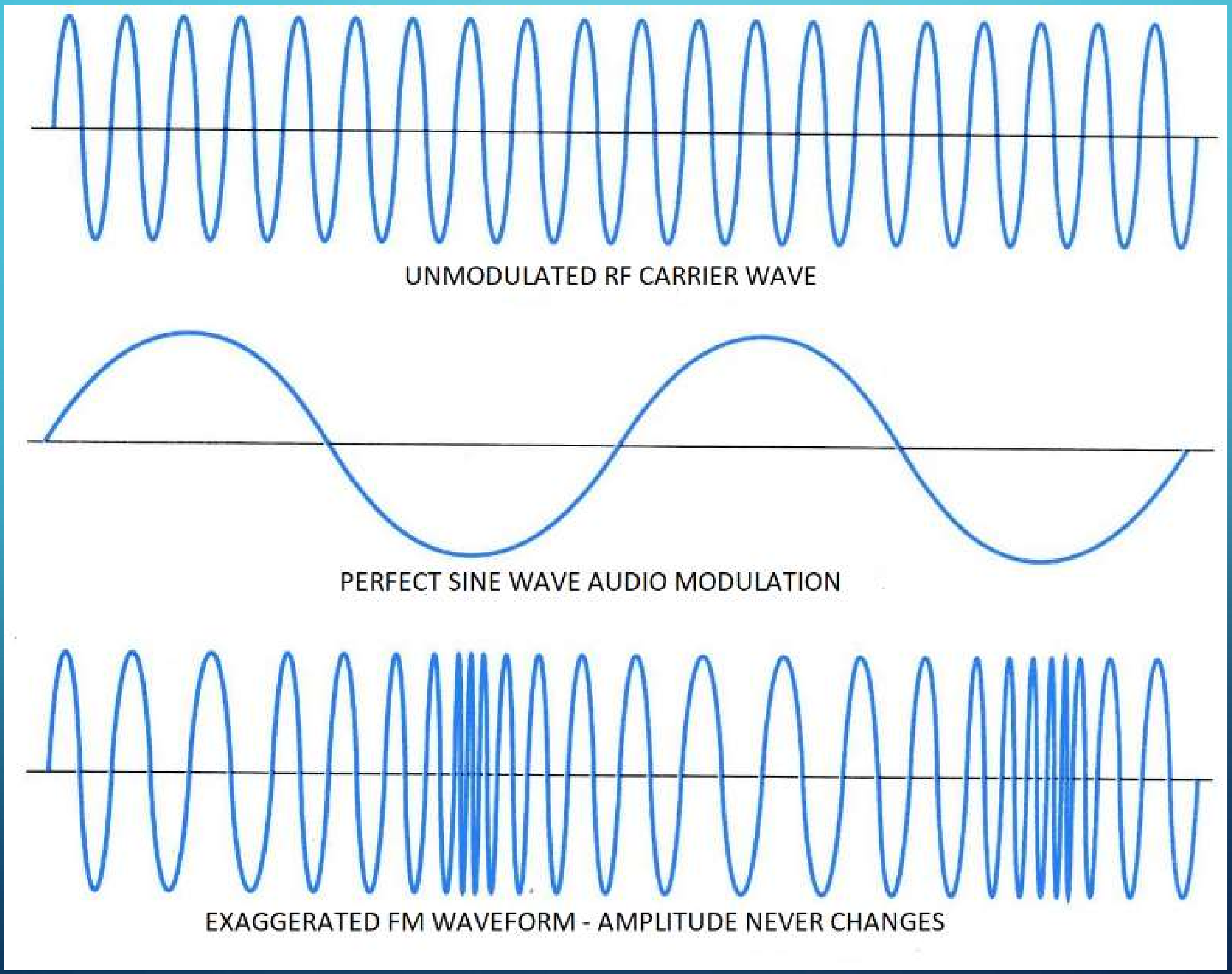
---100%

- THE PEAKS REACH THE TOP AND BOTTOM OF THE BLACK AREA. THINK OF THOSE AS 100W POWER LIMITS.
- **LOOK HOW MUCH MORE BLACK SPACE THERE IS** WITH NO WAVEFORM IN THE BOX OVERALL.
- CAN YOU SEE WHY UN-MODIFIED SPEECH RESULTS IN LOW SSB DUTY FACTOR.
- AND DON'T FORGET TO IMAGINE PAUSES BETWEEN WORDS AND BETWEEN THOUGHTS.
- 'Christoforo' is 'Christopher' in Italian, spoken here in about 1.3 seconds.

USING 'COMPRESSION' INCREASES % AVG POWER AT THE EXPENSE OF FIDELITY - BUT SPEECH INEVITABLY CONTAINS SILENCES + CHANGES IN AMPLITUDE. THIS WILL REDUCE AVERAGE SSB POWER SIGNIFICANTLY.

STEADY SINE WAVE TONES (AS IN FT8) ARE COMPLETELY DIFERENT AND CAN MAINTAIN STEADY 100% - THE AUDIO SIGNAL IS 100% PEAK TO PEAK AT ALL TIMES. THE BLACK WOULD ESSENTIALL DISSAPEAR.

3.3 FM 100% D.F. – RF POWER NEVER CHANGES



---100%

---0%

---100%

No matter what the level of the audio wave at any instant, the RF waveform remains at 100% of the selected PEP power.

---100%

---0%

---100%

CALCULATOR DEFAULTS FOR DUTY FACTOR:

- We assume 44% for CW
- We assume 20% for SSB (voice)
- We assume 100% for FM
- We assume 100% for DIGITAL (Even if sent SSB, it's with near100% tone modulation, unlike our voices).

4. HOW LONG IS THE EVENT, INCLUDING BREAKS?

- Event duration is important and varies a lot: Radio in the park: 4-6 hours. Field Day: 24 hours. Emergency power outage: Days-Weeks?
- For short events it may be practical to run on battery power alone.
- For long events an ability to recharge batteries or avoid battery use is needed. AC mains, solar, generators, etc.

NOTE: Having some means to recharge also permits smaller/less expensive batteries. Also, batteries are helpful in supplying brief PEAK currents we need during transmit, and can be recharged at lower average rates. One long-event battery capacity challenge can be overnight generator 'quiet hours' in RV parks., if operating 24 hours. More on this next time.

5. WHAT % OF EVENT TIME IS RADIO-ACTIVE TIME

- Ya gotta sleep sometime, right? But it's not about you … what's the radio doing?
- Base your calculations on what the radio and battery are doing. Do they sleep?
- Does a relief operator keep the RADIO busy while you rest, eat, socialize?
- What is the real radio down–time. (We assume it is TURNED OFF!)
- Be as realistic as possible in your estimate.

6. WHILE RADIO-ACTIVE, WHAT % TX, % RX, % STBY?

- For radio-ON periods: What is average % time in TX, % time in RX, % time Standby (if applicable – squelched FM only). Must add up to 100%.
- Use the SUSTAINED averages during radio-on periods. You need time to listen. NOT the % TX during the busiest moments.
- At 25% TX during active time you are very busy, probably contesting. (Maybe if you can sit and call CQ ('running') you could get closer to 50% TX for some periods, but what can you sustain throughout your radio-active time?
- For casual non-contact relaxed use you might estimate around 10% or less TX%.

7. INCLUDE ANY ACCESSORY LOADS (OR AVOID THEM)

- Determine accessory AVERAGE current drain during use.
- Determine the percentage of event time that accessory will be in use.
- Include these factors in calculation.

<u>CONSIDER:</u>

- Your radio battery may be specialized and expensive, with high performance in peak current, capacity, etc. Do you want to consume that resource powering things that might be supplied by other means?
- Pick no-power or low power antenna tuners, etc.
- Separate power source for computers, etc.

TAKE A LOOK AT THE EXCEL CALCULATOR PROVIDED

CALCULATOR RESULTS: TOTAL AMP-HOURS CONSUMED

THIS IS CONSUMPTION **NOT** BATTERY RATING. FOR SOME TYPES RATED CAPACITY MUST BE MUCH HIGHER

IC-7300 **PER MFR'S SPECS** @ 100W PEP, 25% TX 75% RX, 5A TX idle minimum except as noted:

ACTIVITY Tot HRS/Active HRS	SSB Ah: 20% TX Duty Factor	CW Ah: 44% TX Duty Factor	FT8 Ah: 100% TX Duty Factor	Same FT8 but only 50 Watts PEP
Field Day: 24/20	59 Ah	78.2 Ah	123 Ah	83 Ah
Park Radio: 6/6	17.7 Ah	23.5 Ah	37 Ah	24.9 Ah
10 hours F.D. night ops = generator quiet hours	29.5 Ah	39.1 Ah	62 Ah	41.5 Ah

FT-991A **PER MFR'S SPECS** @ 100W PEP, 25% TX 75% RX, 6A TX idle minimum except as noted:

ACTIVITY Tot HRS/Active HRS	SSB Ah: 20% TX Duty Factor	CW Ah: 44% TX Duty Factor	FT8 Ah: 100% TX Duty Factor	Same FT8 but only 50 Watts PEP
Field Day: 24/20	75.5 Ah	96 Ah	143.5 Ah	101 Ah
Park Radio: 6/6	22.7 Ah	28.8 Ah	43.05 Ah	30.3 Ah
10 hours F.D. night ops = generator quiet hours	37.8 Ah	48 Ah	71.8 Ah	50.5 Ah

Mfr's. specs. are usually more conservative than actual typical values so you might see slightly less consumption.

RESULTS ADJUSTED FOR PUBLISHED/MEASURED VALUES

IC-7300 ADJUSTED TO PUBLISHED TYP VALUES, 100W PEP, 25% TX 75% RX, 5A TX idle- except as noted:

ACTIVITY Tot HRS/Active HRS	SSB Ah: 20% TX Duty Factor	CW Ah: 44% TX Duty Factor	FT8 Ah: 100% TX Duty Factor	Same FT8 but only 50 Watts PEP
Field Day: 24/20	54.5 Ah	70.5 Ah	108.3 Ah	74.5 Ah
Park Radio: 6/6	16.3 Ah	21.1 Ah	32.5 Ah	22.4 Ah
10 hours F.D. night ops = generator quiet hours	27.2 Ah	35.3 Ah	54.1 Ah	37.3 Ah

FT-991A ADJUSTED TO PUBLISHED TYP VALUES, 100W PEP, 25% TX 75% RX, 6A TX idle- except as noted:

ACTIVITY Tot HRS/Active HRS	SSB Ah: 20% TX Duty Factor	CW Ah: 44% TX Duty Factor	FT8 Ah: 100% TX Duty Factor	Same FT8 but only 50 Watts PEP
Field Day: 24/20	72.1 Ah	88.4 Ah	126.5 Ah	92.5 Ah
Park Radio: 6/6	21.6 Ah	26.5 Ah	38 Ah	27.8 Ah
10 hours F.D. night ops = generator quiet hours	36.1 Ah	44.2 Ah	63.3 Ah	46.3 Ah

Mfr's. specs. are usually more conservative than actual typical values so you might see slightly less consumption.

SOME MANUFACTURER'S RADIO SPECS USED IN CALCULATIONS:

ALL CURRENTS IN AMPERES. Some additional results from QST and other reviews included in parentheses.

Specification	IC-7300 100W HF SDR	FT-991R 100W HF +50W V/U	ID-5100A 50/15/5W VHF/UHF MOBILE FM	FT-60R 5/2/0.5W VHF/UHF HANDHELD FM
Voltage	13.8V +/-15%	13.8V +/-15%	13.8V +/-15%	7.2V Nominal or 13.8V Adapter
TX Current Drain at Full output power	21 (QST 18.5A)	23 (QST 19.6A for non –A version)	13 (QST 12A-UHF, 10A-VHF). (15W=6.7/5.3A; 5W=3.5/3.4A.	1.55 (avg of 1.5 VHF and 1.6 UHF)
RX Current Drain	1.2 (QST 1.05A max audio)	2.2 (QST 1.58A but with no signal!! Add 0.3A for full audio, use 1.9A)	1.8 (QST 0.63A w/1RX. Add 0.2A for audio, use 0.83A)	0.125
Standby Drain	0.9 (no test result)	1.8 (no test result, decreased to 1.5A)	1.2 (QST 0.45A)	0.019 w Pwr. Saver
Estimated Min. Pwr. TX Current Drain (not specified by mfr.)	Used 2A (AB4OJ meas. 5.7A @ 5W PEP:Experimentally 5A TX idle current).	Used 2A (QST meas. 6.8A @5W PEP:Experimentally 6A TX idle current.	Used 2A. Per above, s/b 3.5A for 5W UHF. Experimentally 2.55A TX idle current.	0.5

Mfr's. specs. are usually more conservative than actual typical values so you might see slightly less consumption. But estimated TX idle current value of 2A used probably low so you might see higher Ah at QRP and SSB mode.

AMP-HOUR CAPACITY VS. ABSOLUTE PEAK DEMAND

- We've estimated Amp-hours of charge capacity required using loads averaged over time.
- Another key limit is the ability of the power source to supply shorter term PEAK current in Amps, such as when we transmit – probably the heaviest load.
- Make sure your battery or power supply can sustain that peak current (Amps) for transmit periods -- and do so without voltage sagging below your allowed minimum (probably around 11.7V). Again: More on this next time….

FUTURE INSTALLMENTS INTENDED:

Part 2: BATTERY TYPES COMPARED

- Battery chemistries differ in cost, weight, lifetime, safety and performance. For some types you will find that as much as half of 'rated capacity' is useless to you.

Part 3: SIMPLE SOLAR PANELS AND CONTROLLERS

- Adding solar or other means of replenishing your battery can extend operating time and/or allow you to use a smaller battery. As some battery types are expensive, depending on your operating intentions it can be good economics to include a recharge capability. But prime daylight hours are limited.   Is portability important?

Part 4: GENERATORS AND INVERTERS

- Fossil fuel generators provide lots of power for multi-radio sites but are heavy and noisy. Their use may be limited during quiet hours in some parks. You may need battery to get thru the night and a battery covers service intervals.

APPENDIX: NOTES ON FORMULAS IN SUPPLIED EXCEL CALCULATOR

The results are in the blue shaded cells from B28 down to B34, with the most important result in B34.

1. B6 shows the portion of peak transmitter current (Amperes) when at full power that is affected by power changes set in the radio's controls. It assumes that the value in B5 must exist even at zero Watts out. Thus, the value in B6 equals the peak transmitter current minus the zero-power current in cell B5. This remaining range of current is what varies as we vary transmitter power.
2. B28 shows the modulation mode Duty Factor % selected from the table on rows 20-25 per cell B9.
3. B29 is the expected actual AVERAGE DC current draw (Amperes) in from the battery, for the conditions specified, during the time periods that the PTT is pressed or CW code is being actively transmitted. It is calculated as: **(B2 minimum transmit current) + [(B28 transmit Duty Factor) X (B6 Varying portion of transmitter current) X (selected % of full transmitter power)**
4. B30 is the expected actual AVERAGE DC current draw (Amperes) for Active Radio Time (not including rest periods) for the combined mix of transmit/receive and standby percentages. It is calculated as **[(B12 % transmit time) x (B29 Average Transmit Current)] + [(B13 % receive time) x (B7 Average Receive Current)] + [(B14 Standby Time) x (B8 Average Standby Current)]**.
5. B31 is the expected actual AVERAGE DC current draw (Amperes) over the entire event period in cell B18, including rest periods. It assumes the radio is OFF during rest periods and is calculated as **[(B30 Average DC Current Draw during Active period) x (B10 percent of time Active)]**
6. B32 is the Average DC current draw for accessory items (Amperes) averaged over the total event time. It is calculated as: **[(B16 Average accessory load current when active) x (B17 % of total event time when accessories are active)]**
7. B33 is the Total Average DC current demand (Amperes) for all loads, averaged over the entire event time is calculated as: **[(B31 Average radio current) + (B32 Average Accessory Current)]**.
8. B34 is the total Ampere Hours needed from the power source. (Battery?). It is calculated as: **(B18 Event Hours)** X (**B33 Total Average Current Draw)** and is stated in Ampere-hours. For battery sources the USABLE capacity must be greater than this number while maintaining the minimum required operating voltage under load.

QUESTIONS?

THANK YOU!

The calculator and a written explanation in more detail will be posted on the website along with this PowerPoint deck. Again:

Make your own measurements for highest accuracy.

PLEASE be careful.

And please advise me of any errors so that they can be corrected.