

# Theory and Practice of Rb Frequency Standards

Doug Millar K6JEY

SBMS

# Information

- This is a general talk about Rubidium Oscillators and meant for those who have just bought their LPRO oscillators. I have had to strike a balance between technical information and practical information. The workings of “atomic clocks” are very interesting. Consult the sources listed below.

# History of the Project

- A couple of months ago Robin WA6CDR and I decided that we should try to acquire enough units of an inexpensive Rubidium (Rb) oscillator so that as many microwavers as possible could put them in their rigs. That way stability and accuracy could be improved for the group. We expected our initial order of 30 or so would be enough. We had that many orders in an hour. We are now up to 180 units and they are nearly spoken for.
- Each unit is checked for proper operation and lock but not calibrated. Real calibration is a labor intensive job. However, we have found that the units are amazingly close in frequency and we are sure that you will not be able to tell one from the other in frequency in normal operation.
- Do not, unless you have experience and a lab, do any adjustment on the oscillator.
- Do write down the lamp voltage and crystal voltage and check it once a year.
- The connector is very common.

# Comparison of Oscillators

	Cesium	Rb	OCXO
Accuracy	$5e-13$	$1e-12$	$1e-10$
Aging	N/A	$5e-11/\text{Mo}$	$5e-10/\text{day}$
Ph Noise	-130dbc	-130dbc	-140dbc
Warm Up	10min	2-30min	30min
Stability	$1e-14$	$3e-12$	$1e-10$
Cost	\$60K	\$60	\$100

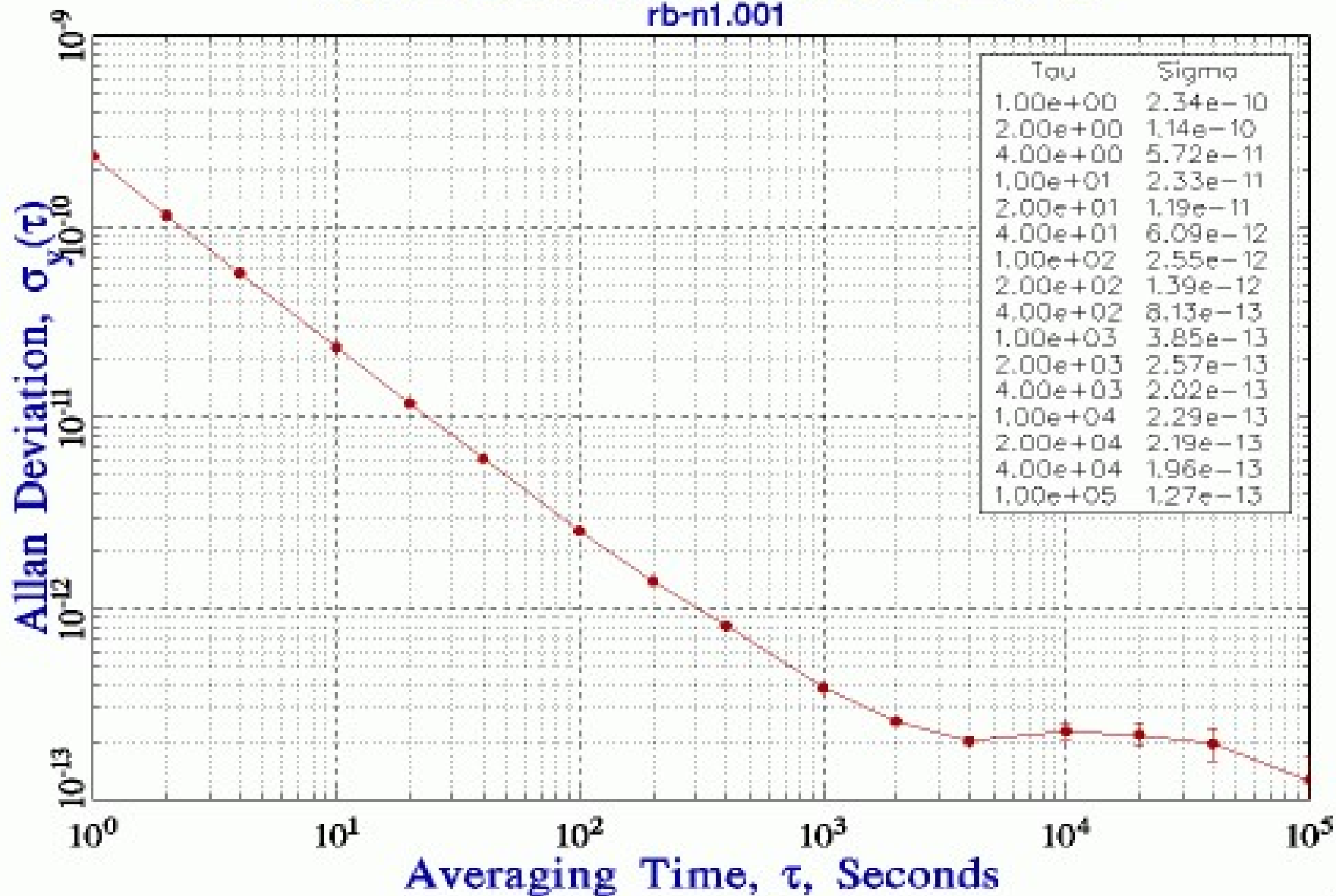


# Rb Stability Chart

- The chart is for an HP Rb
- One hour is 3.6k seconds
- One day is 86.4k seconds
- One week is 601k seconds
- Ten days is 864k seconds

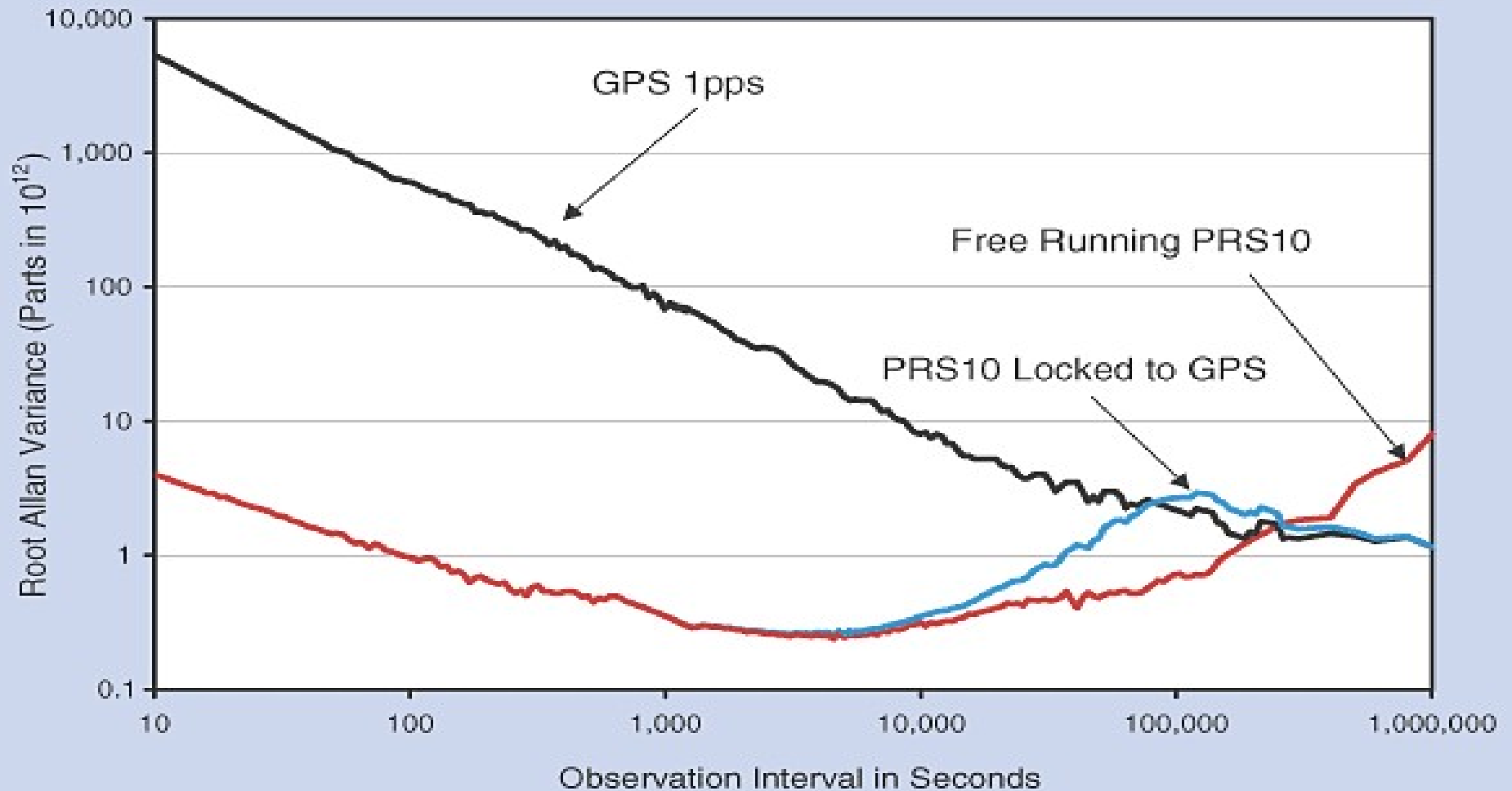
# FREQUENCY STABILITY

rb-n1.001



# GPS Lock Data

1 hour = 3.6k sec, 1 day = 86K sec

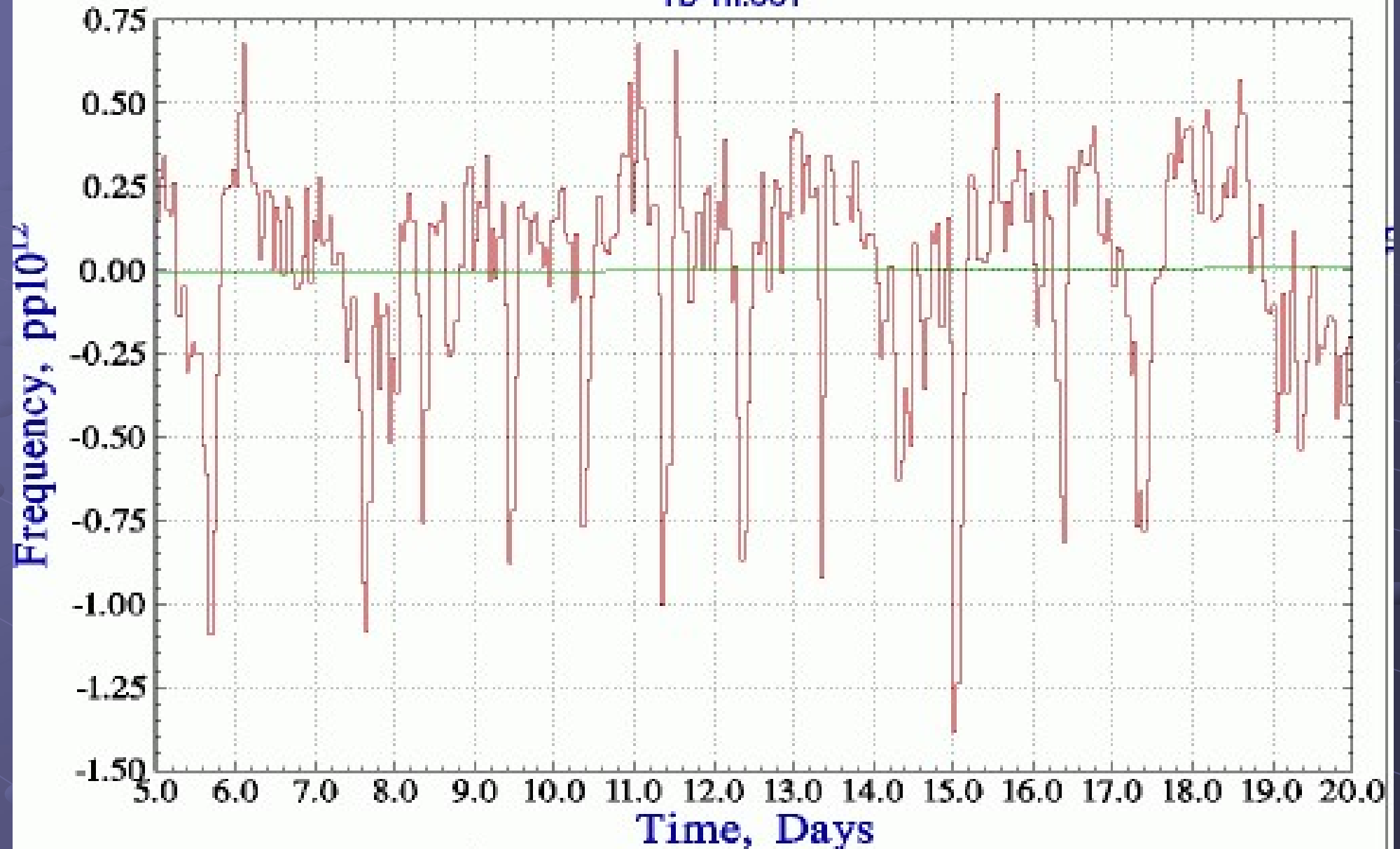


# Interesting Variations

- This chart shows accuracy at  $10e-12$  and lower that occur over a period of time but that are not related to drift of the Rb. Some variations happen at the same time (midnight!) and may be temperature related.
- Rb's are affected at these levels by forces that are not well known. Some effects have to do with the Rb gas mixes, which limits their accuracy in some situations.

# FREQUENCY DATA

rb-1h.001



Linear Fit:  $y(t)=a+bt$ . Intercept= $a=-1.4041858e-14$ . Slope= $b=4.6751107e-17$

# Rb Ephemeris

- There are diurnal effects on frequency
- Practically stability can be  $2e-12/\text{mo}$ .
- Daily average frequency can be parts in  $10e-13$ .



# Some Advantages of an Rb Over an OCXO

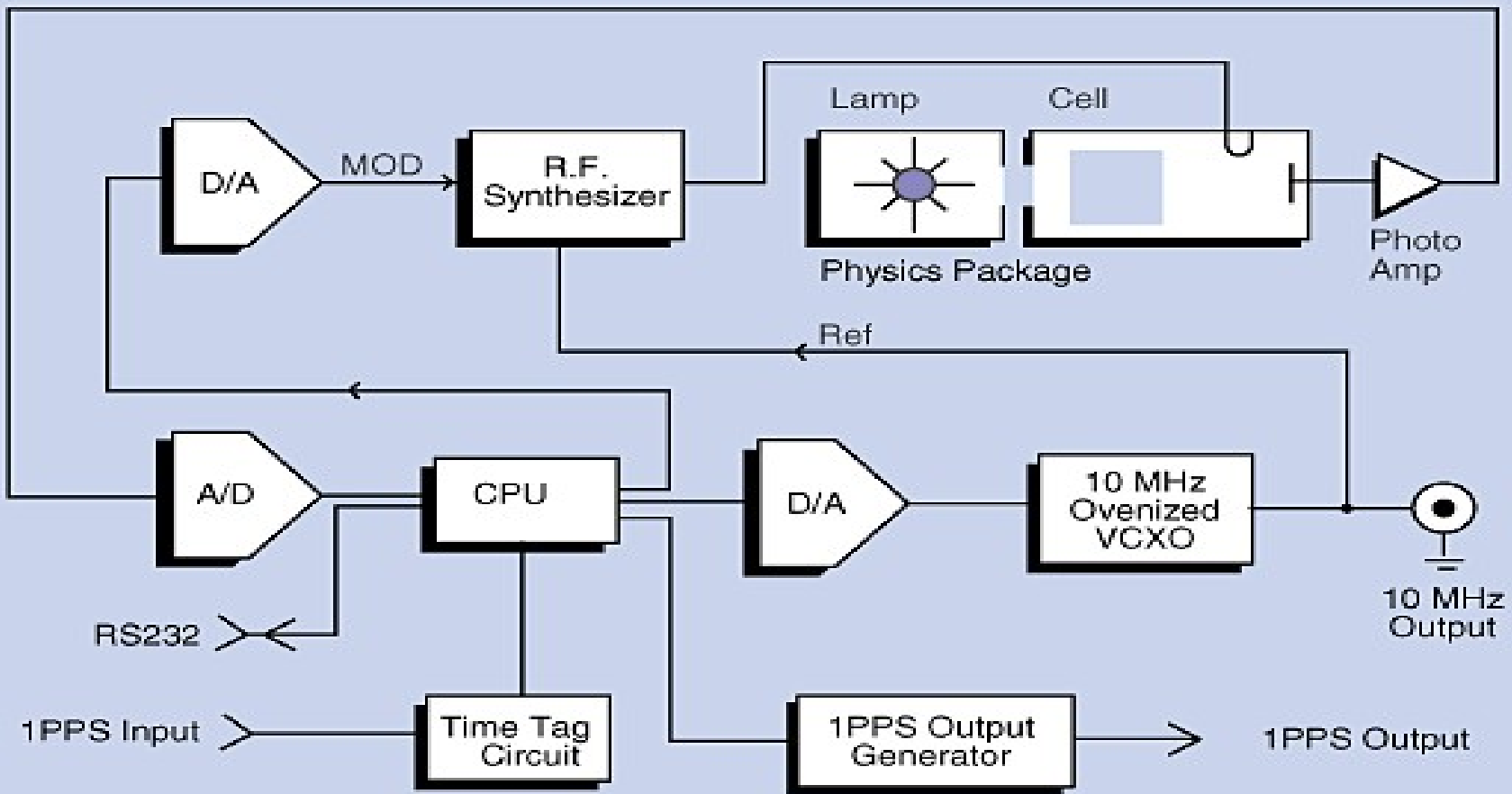
- Less need for calibration
- Much greater stability in the field.
  - Less affected by temperature and vibration
  - Less sensitivity to voltage changes.
  - Used Rb's a better gamble than used OCXO's

# How does an Rb Work?

- Simply, the “atomic package” has a lamp with  $\text{Rb}^{87}$  gas in it that is heated by RF.
- The Rb radiation is sent through a chamber with  $\text{Rb}^{87}$  in it .
- A photo cell on the far side detects the amount of light reaching it.
- When the chamber is fed with RF at 6.834,685Ghz the light level changes.

- The photocell is servoed to the oscillator and the oscillator is kept at the null in intensity. A 10mhz oscillator is linked to the servo and the stability of the null is reflected in the 10mhz output.
- The physics package has to be calibrated when it is built and has to be recalibrated as factors change in the physics package.
- Depending on how robust you make the physics package the oscillator and lamp will last longer and be more tolerant of outside forces like magnetism and temperature.
- The calibration mechanism is to change the C field, which is a coil around the package that effects the Rb gas resonance.

# Block Diagram of a PRS 10



- In practice Rb's are so tough some have been space qualified.
- They have an ordinary life of 15-20 years.
- By keeping track of the lamp voltage, one can chart how old the Rb is getting.
- Other than the lamp itself little else seems to go wrong.

# Now Some Details about Three Types of Rb's

- Efratom FRK –
  - Old (1970's technology)
- Efratom LPRO-
  - Modern and inexpensive
- Stanford Research Associates PRS 10-
  - New and well engineered.
  - Expensive



# Efratom FRK

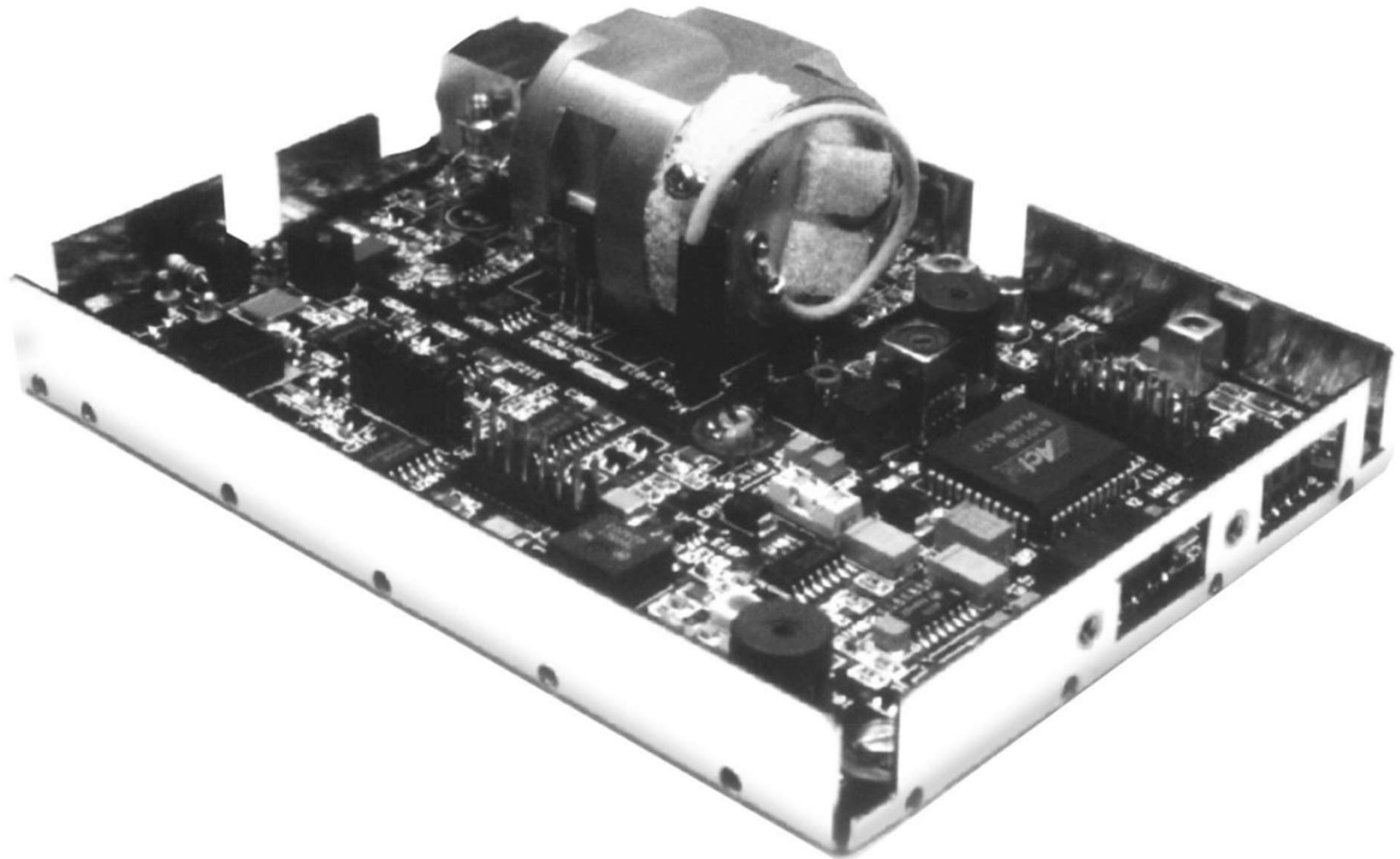


- The FRK series were the best of the original types. All analogue, brute force physics package and well shielded. All discreet components. Mine still works fine. They are big in comparison to the LPRO. TTL or Sinewave output.
- They are probably the most stable Rb's next to the PRS 10.
- FRS-C is a miniature version and is more susceptible to magnetics and a little less stable.

# The LPRO Rb

- Trimble originally made them to be inexpensive, robust and maintenance free.
- They designed it for 10 year full time service life.
- They have an ultra small physics package and a lesser amount of Rb<sup>87</sup> loaded in them.
- Cost is very reasonable. Eg. If yours dies, get another one.

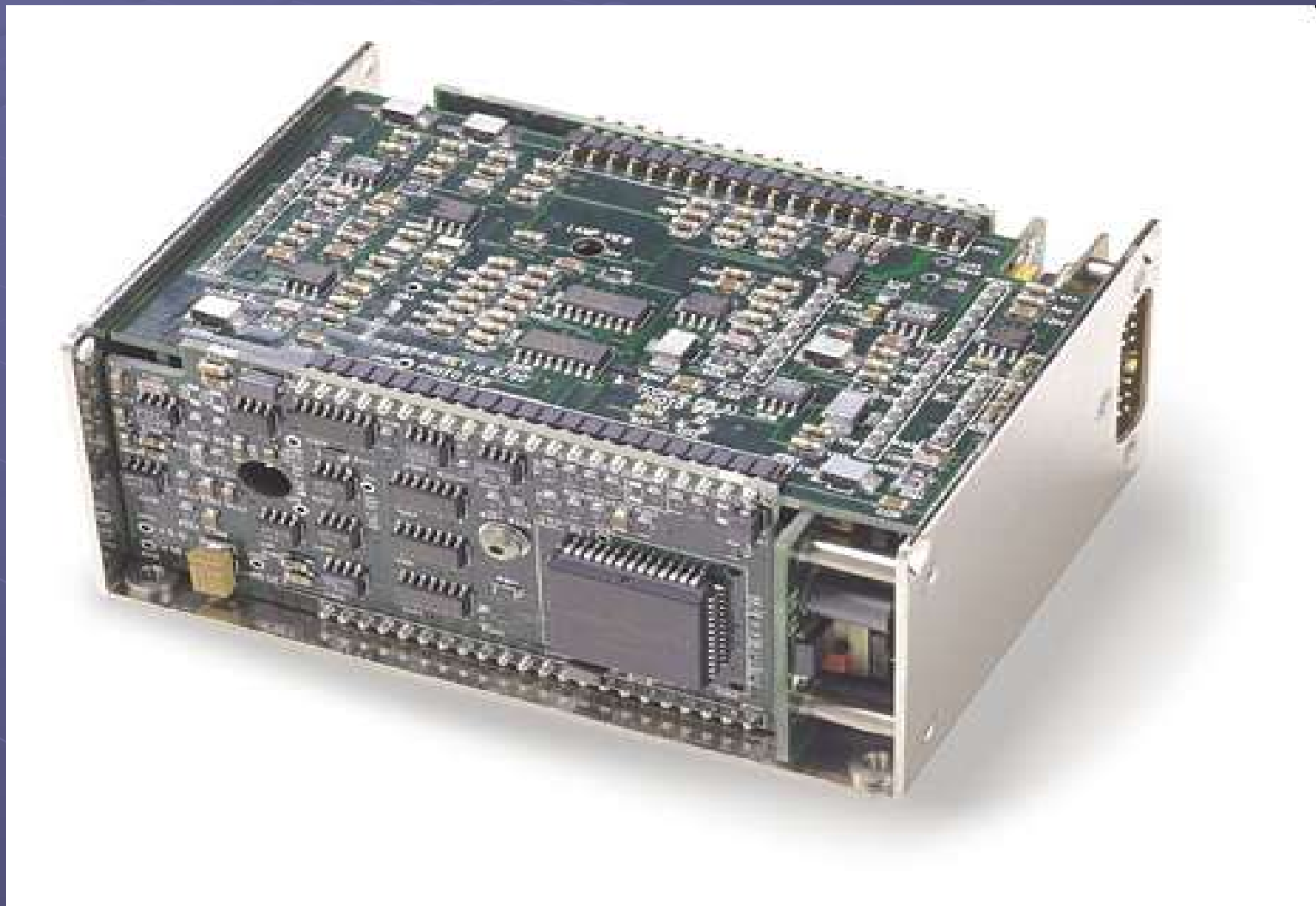
# LPRO Insides



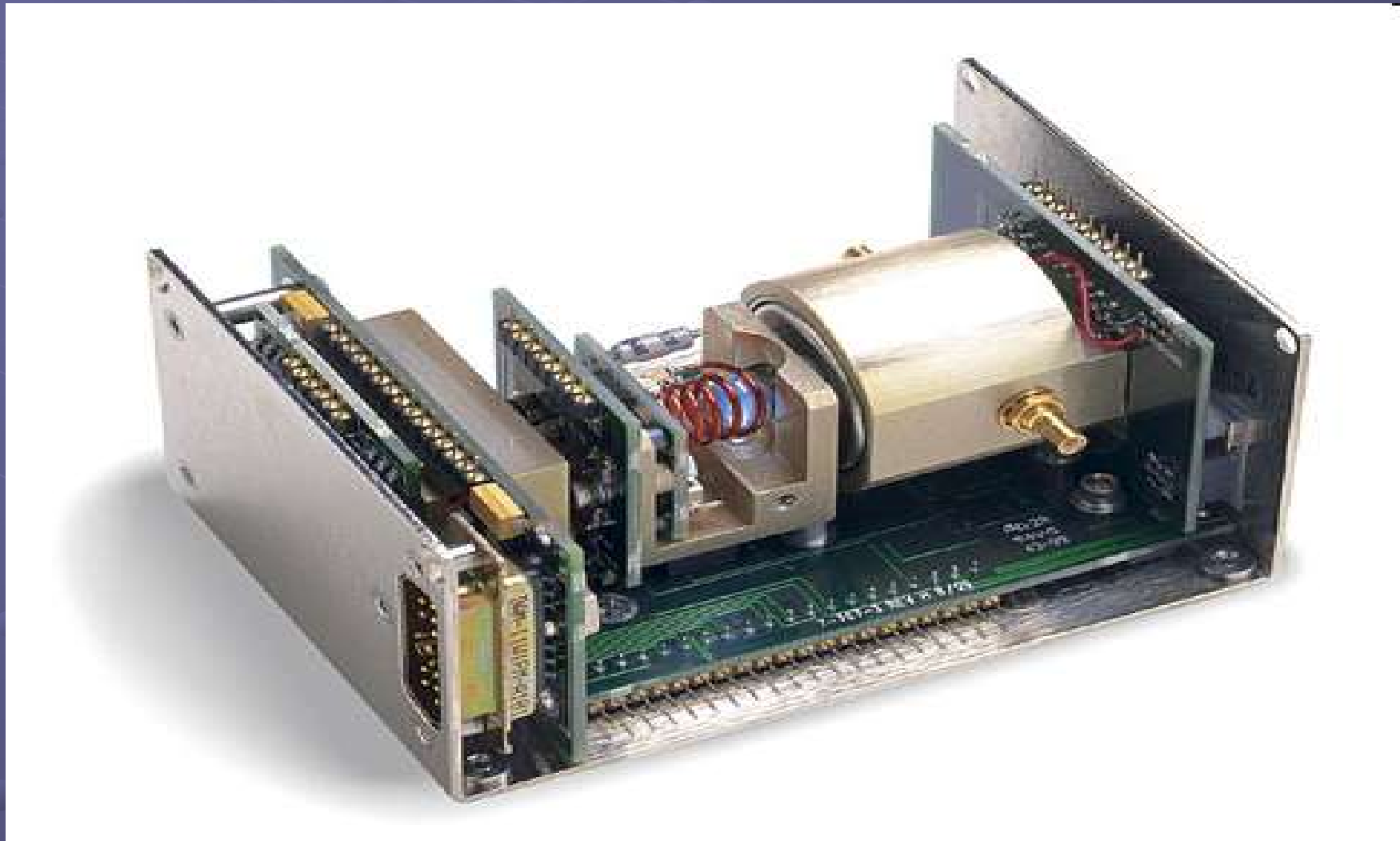
# PRS 10 Assets

- It has a 20 year lamp life
- Has an internal CPU that estimates a 72hour hold-over. Turn it off and on and it comes right back to frequency.
- -130db/hz @10hz Phase noise
- RS 232 communications to and from Rb
- Cost \$1400 (\$400 surplus)

# The PRS 10 Inside is Busy



# PRS 10 Without Boards





# What is the Difference?

- From the other station's point of view, all of them will keep you within 10hz for a month at 10,368.125,000mhz.
- The LPRO's are cheap and plentiful, others are more expensive and/or older.
- So, use of any Rb will dramatically improve your rig's stability, but the LPRO does represent an inexpensive choice.

# Care and Feeding

- Make sure your power supply is filtered.
- Keep it away from strong magnetic fields.
- Consider a sun shade if used portable.
- Use a heat sink. Almost any base plate will do. The internal regulator is 17v, so a supply of about 20v will dissipate less heat than higher voltages.
- Write down the lamp voltage and crystal voltage for trend analysis.

# In Operation

- When the Rb locks it will be about  $1e-10$ . After 30 minutes it should be  $1e-11$ . that means that you will be within 50hz at 10ghz at lock, and stabilize to better than 10hz in the next few minutes. **Do not attempt to adjust it unless you have a good time lab.**
- The LPRO's lock after more than 2 minutes and go to better than  $10e-10$  at that time. Have a lock light to tell you when you are locked. A schematic for one is on the SBMS website.
- You might want to test your IF rig for stability to see how much it contributes to the total drift. Eg. You might want to get a TCXO for your FT 817.

# Further Information

- For more information here are some resources. A good spot is this site- go to the PRS 10 ad and look for the data sheet and manual.  
[www.thinksrs.com/products/PRS10.htm](http://www.thinksrs.com/products/PRS10.htm)
- Some of the graphs were taken from:  
[www.febo.com/time-freq/index.html](http://www.febo.com/time-freq/index.html)  
Tom's website has excellent info.
- The SBMS website has the LPRO manual and a lock light design: <http://www.ham-radio.com/sbms>



Thanks

Doug K6JEY

[dmillar@moonlink.net](mailto:dmillar@moonlink.net)