A Comparison of Wattmeter Accuracies at 1296MHz
Based on Calorimetric Measurements

by
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The purpose of this paper is to measure the accuracy of a variety of UHF watt meters at 1296MHz to see what their error is. Most of the meters are not specified at this frequency, so this will be new data. Common knowledge supposes the additional error may be 10%

There are very few meters that are accurately calibrated at 23cm and at high power. I have been using a Bird 6091 calorimeter. It is one of the few meters that can do this type of measurement accurately. Its accuracy is 1.25% of reading. Its range is 0-2500 MHz Its measurement range is 10 to 250 watts.

In doing measurements of this type it is good to be aware of some of the sources of error. Steve, K1FO emphasized that both lie SWR and element directivity can have a negative effect on accuracy. His paper is in the resource section. In the testing set-up, I used a single double female N connector to connect wattmeters to the calibrator.

I compared an HP 436/8487A and attenuator in current calibration with the Bird 6091 at 10watts on 144MHz and found that the two meters agreed to within 1%. This verified that my measurements would be accurate enough to be meaningful.

The idea was to take a group of randomly selected meters and test them in their intended range and then at 23cm and see how their accuracy changed. All the meters were used and except for some minor repair, all were tested as found, simulating “that great swap-meet deal”, rather than using all new meters.

Most of the meters tested were specified at 5% accuracy as a percent of a full scale reading (OFS). On a 25 Watt scale a 10 Watt reading could be off by 1 Watt. Some were specified at 5% of reading. This is a significantly better accuracy. On a 25 Watt scale a 10 Watt reading would be off by no more than 1/2Watt. The source data shows that some meters looked better than they were at low ends of the scale.

Wattmeters read power as a voltage. Using E^2/r produces a scale with ¼ power at mid range. This scaling helps compensate for the 5% ofs accuracy problem at low power. Somehow the Struthers meters use a linear power scale.

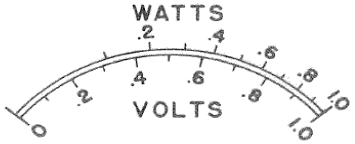


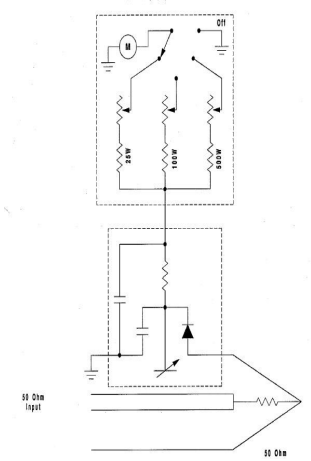
Fig. 2-2. Square law scale, watts vs. volts

Thruline Series

- Bird 43- Uses elements with a directivity of about 17-20db. Specified at 5% OFS.
- Bird 4410- special elements with 7 ranges as part of a bridge for thermal stability. 5% of reading accuracy.
- Bird 4304- Multi range meter with two couplers. Needs calibration graph below 100MHz. Great from 144MHz to above 1000MHz. 5% OFS

Termaline

- Sensors are a capacitive voltage divider * and have a broader frequency response than the regular inductive elements. At higher power all the elements seem to have a flatter frequency response. They are more accurate when one end is attached to a load. But work fine as pictured.



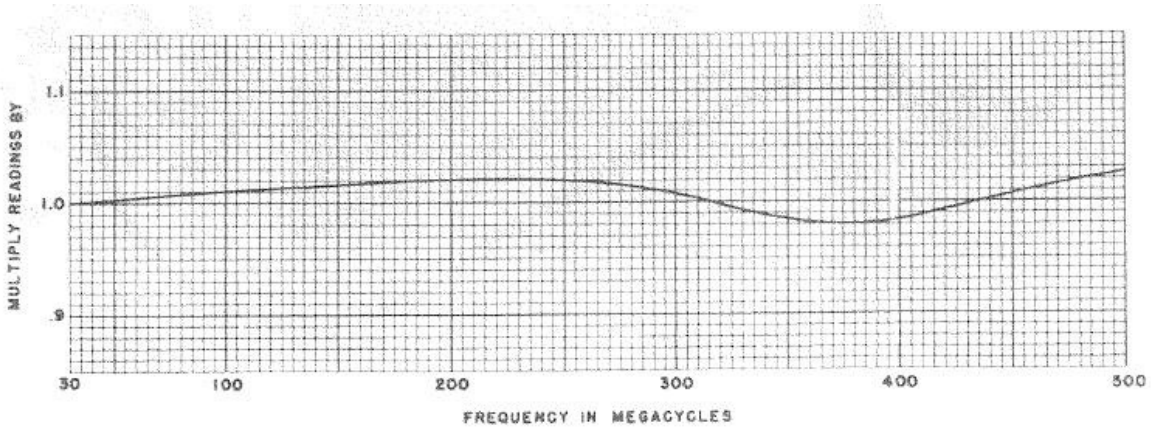


Figure 7-1. Typical Power Calibration vs. Frequency Curve (K factor)

Micromatch

- All of the Micromatch single range boxes tested inconsistently from box to box. Accuracy vs. frequency range seems to be good however.
- Several of the multi range box 711 tested did not meet specifications unless calibrated on a single frequency. Scale to scale readings off on the low ends, even after calibration.
- The Heathkit IM4190 tested well at 432 and 23cm.

R&S NAUS

- The dial calibration intervals did not give as good a resolution as other meters tested.
- The meter was not as accurate as I thought it would be, although it met specifications.
- The meter itself is extremely well made with one of the best couplers I have ever seen and very rugged.
- The coupler diodes can be easily blown in the low power direction and are custom made and extremely hard to find.

R&S NAP

- The finest meter tested. Easily met specifications of 5% of reading on all frequencies.
- Wide variety of measurements possible. Analogue and digital display.
- Sturdy and robust.
- Operated from either Ac or rechargeable batteries
- A number of sensors available.
- Expensive relative to the other meters.

Struthers

- Relies on mechanical adjustment for calibration. Rough handling and wear easily changes the calibration, but easy to calibrate.
- The lid can fall away from the pot as latches are light duty, and coax cord can pull from connector.
- Usually comes with a several multi range sensors.
- Meets specifications.

Test Results

Bird Meters

Meter	Model	144MHz	432MHz	1296MHz
Bird	4410-6	(4)	0	(-9)
	4304-150W	0	1.2	0
	6737	0	0	10
	6734	0	0	10
	6737	.6	0	10

Notes on Measurements: Numbers in parenthesis are % of reading. All others are % OFS.

Elements

Element	Model	144MHz	432MHz	1296MHz
Coaxial Dynamics	82074	1	1.8	1.6
Bird	500E	1.8	1	0
	250E	1.8	-2	8

R&S Meters

R&S	Model	144MHz	432MHz	1296MHz
NAUS	NAUS	5	5	-17
NAP	1100w element	(4)	(4.8)	(-13)
	350w element	(4)	(4)	(-5)

MicroMatch Meters

uMatch	Model	144MHZ	432MHz	1296MHZ
	120	-19	-15	-21
	400	1.3	1	10

Heathkit

Meter	Range	144MHz	432MHz	1296MHz
IM-4190	30	-11	0	-3
	75	-4	0	8
	300	-	-	15

Struthers/Douglas

Meter	Range	144MHz	432MHz	1296MHz
Struthers				
.2-1GHz element	10	1.4	1	9
	50	1	14	18
	100	3.5	3	7
Douglas				
.2-1GHz element	10	17	0	10
	50	12	25	12
	100	16	22	7

The Struthers meter looked new and tested well on all ranges. The Douglas was calibrated in 1994 but had obviously had rough usage.

Conclusions

- Doing the measurements has been revealing.
- The **Bird 4410** seemed to be the most accurate at all frequencies and power levels
- The **NAP/350** exceeded its specifications.
- The **Bird 4304** more than met specifications and tracked well between ranges. The **Bird Termalines** were very accurate. The **Thruline** elements were all bought used except one made by Coaxial Dynamics and met specifications.

Overall Conclusions

- The data clearly shows that if a meter does well on 432MHz, it will do well on 1296MHz and probably read not more than 10% ofs high. If the meter does not do well at 432MHz, it will not do well at 1296MHz. However, it is worth looking in the detailed measurement results to see how the full-scale calculations work out as a percentage of reading for the meters.

Resources

- K1FO's article on wattmeter accuracy
- Bird Power Point on their metrology procedures and set up.
- Bird's manual on Termaline meters
- Bird's metrology procedures
- The above are all available at K6JEY Presentations or
- http://www.nitehawk.com/k6jey/presentations/