

**A Comparison of Wattmeter  
Accuracies at 1296MHz  
Based on Calorimetric  
Measurements  
by  
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# Purpose

- The purpose of this paper is to measure the accuracy of a variety of UHF wattmeters 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%.

# Measurement Gear

- There are very few meters that can do an accurate calibration at 23cm at high power.
- I have been using a Bird 6091 calorimeter, one of the few meters that can do this type of measurement. It's specifications are-
  - Accuracy 1.25% of reading
  - Frequency range 0-2500MHz
  - Power range- 10-250 watts

# System Calibration

- Steve, K1FO emphasizes that both line 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 HP436/8487A 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.

# Process

- 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.

# Meter Accuracies

- 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 1/2 Watt.
- The source data shows that some meters looked better than they were at low ends of the scale.

# Meter Scales

- Wattmeters read power as a voltage. Using  $E^2/r$  produces a scale with  $\frac{1}{4}$  power at mid range. This scaling helps compensate for the 5% of accuracy problem at low power. Somehow the Struthers meters use a linear power scale.

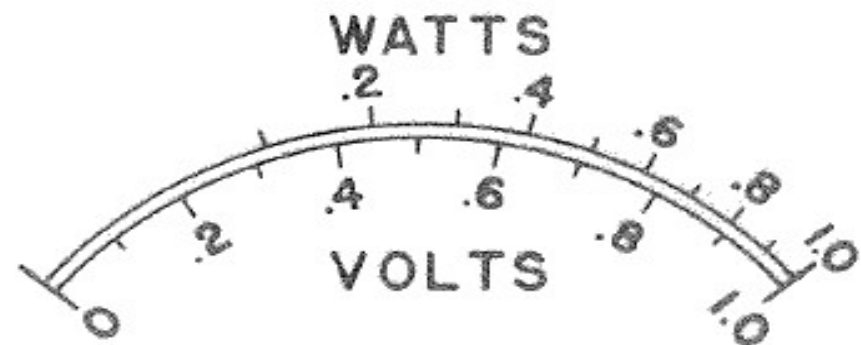


Fig. 2-2. Square law scale, watts vs. volts



# Testing in progress on 23cm

An M/M N connector was used to couple meters under test to the 6091.



(The avocado was not tested for accuracy, but tasted good.)



# Further Testing

- A San Bernardino Microwave Society meeting testing meters at 432MHz and 23cm.
- At this session we found that combinations of elements and meters all read differently, but not necessarily out of spec at 5% OFS.



# Bird 6091

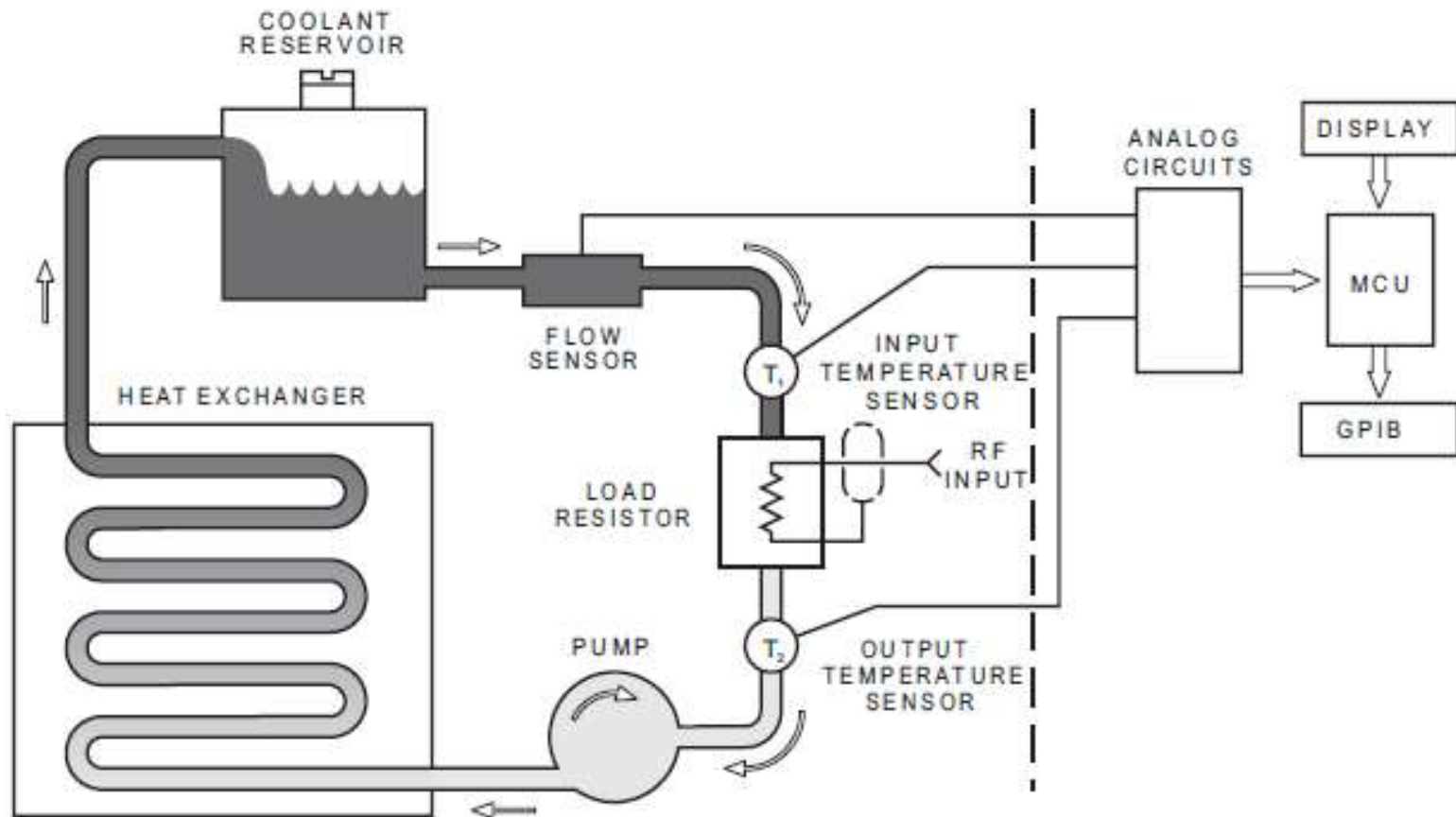
The 6091 uses water for heat transfer and can be calibrated at DC.



# Bird 6091

- Calorimeter diagram

Figure 4  
System Block  
Diagram





# Pictures of the Meters Tested

Bird 43, 4410 and 4304



# 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

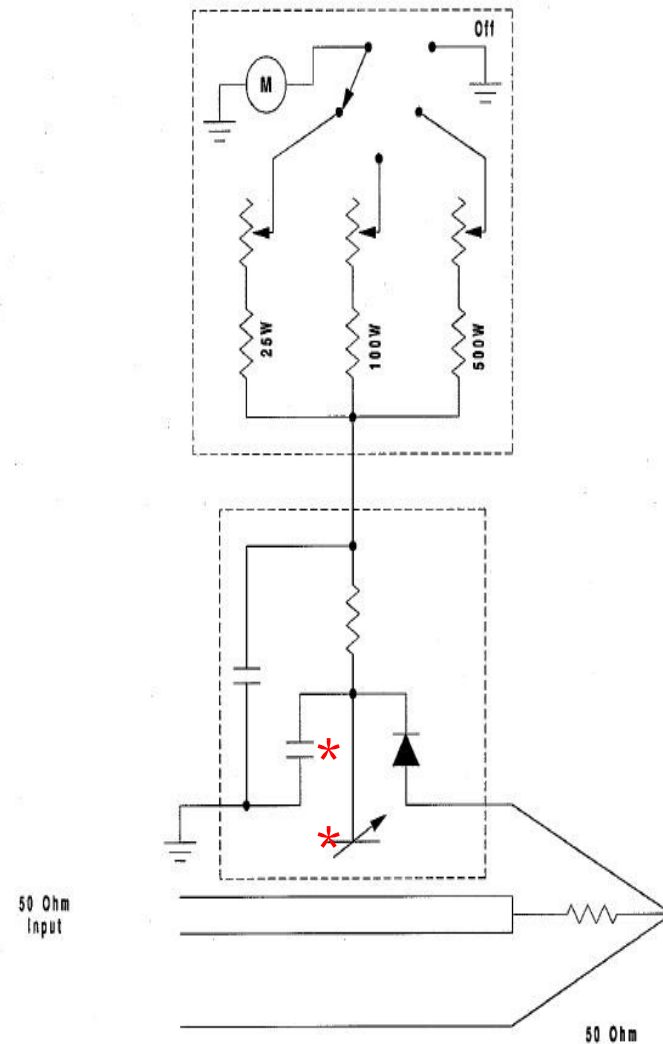
# Bird Termaline

Note the F to F QC coupling block. Models 6737 and 6734.



# Bird Termaline Schematic

- 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.





# Termaline

## Reading error vs. frequency

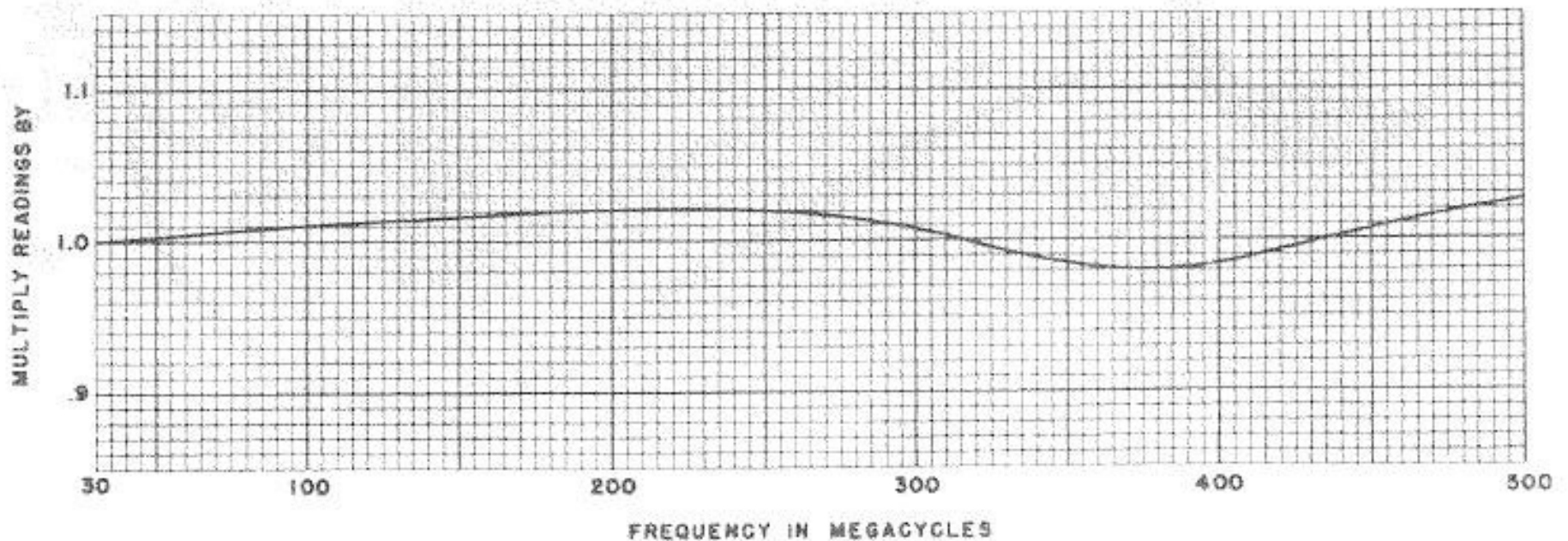


Figure 7-1. Typical Power Calibration vs. Frequency Curve (K factor)

# Micro Match and Heathkit

120Watt

Heath IM 4190

711





# And Friends- Not Tested

- Micro-match
- match



# Little Boxes

- 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



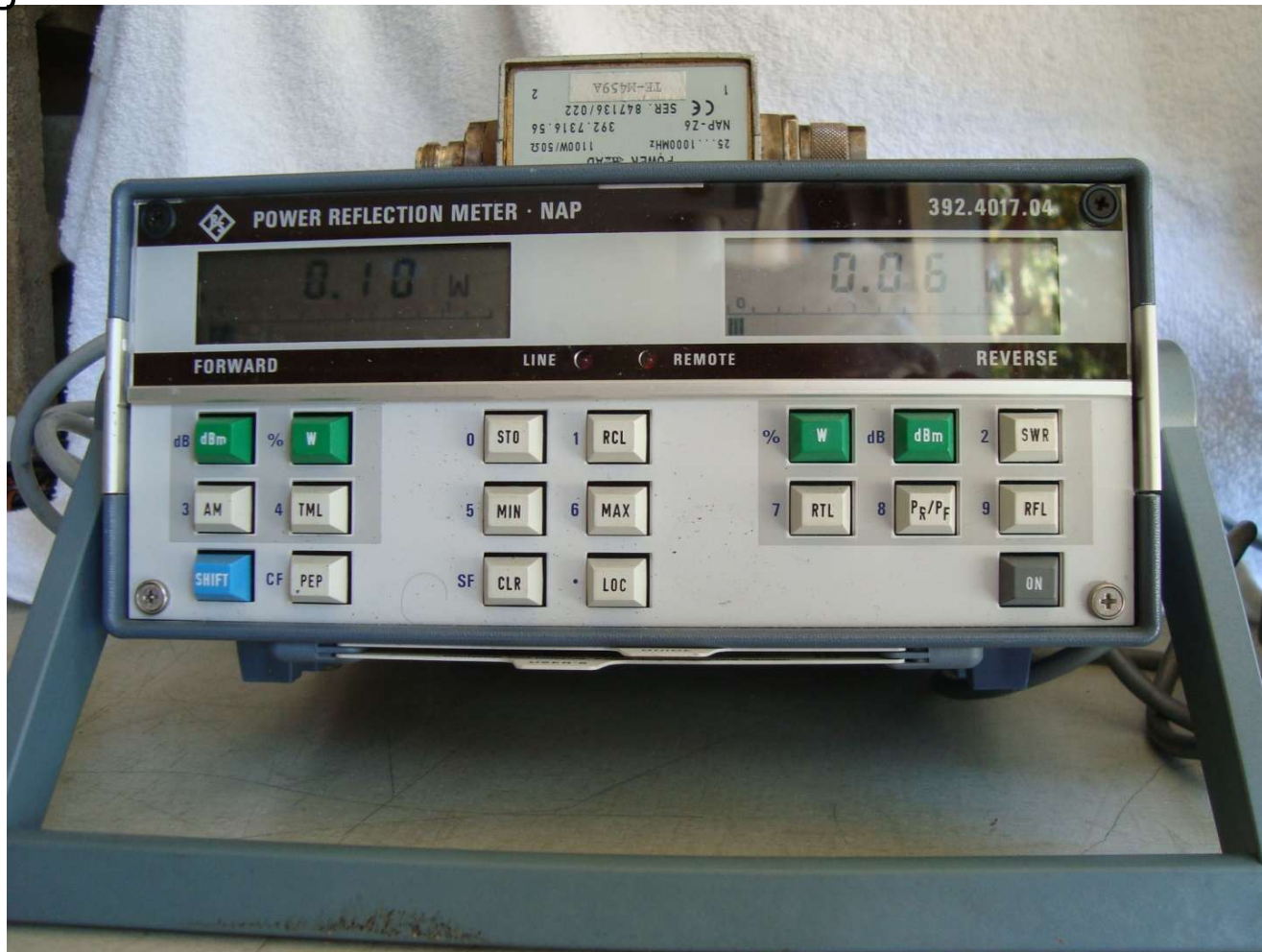


# R&S NAUS

- 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

Easily the most sophisticated meter tested. Battery operated or AC with several sensors available. Dual displays that are analog and digital. Auto ranging as well.





# 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

Also made as Douglas Microwave , Sierra, and others



# 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% of 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.

# Specific Conclusions

- If you have a high power Watt meter that you know is good at 432Mhz, you can use it with some assurance as to its accuracy on 23cm. It will likely be 10% OFS high in reading.

# 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/>



# Thank you for your attention

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