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RF POWER MEASUREMENT of DIGITAL SIGNALS

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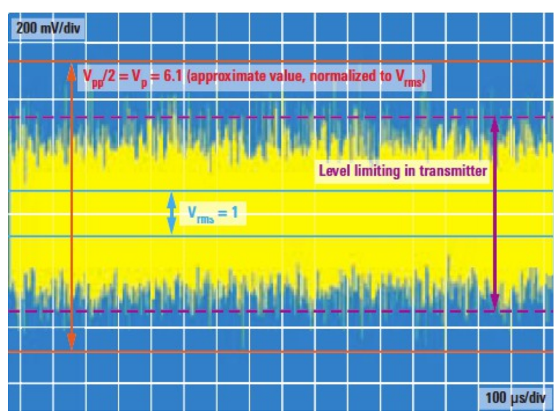
The material in this application note first appeared in the Boulder Amateur TV Club's newsletter, the TV Repeater's Repeater, Jan. 2021, issue #66.

There is a lot of controversy among hams about RF power specs. and claims when it comes to non-sinusoidal rf signals, such as digital TV, D-Star, DMR, etc. The most common rf power meter in ham shacks is one such as a Bird or similar meter. These power meters use a semiconductor diode as the basic detector element. The diode detects the peak value of the rf input signal. Then depending upon the R-C filtering after the diode, the resultant DC voltage can represent either the rf peak or average power. These diode detector meters are all calibrated using CW sine waves. These types of power meters do not accurately measure noise-like digital signals.

Bird RF Power Meter

Now for measuring a digital signal, it is not a simple matter because it's time domain waveform looks just like random, white noise and is no longer a simple sine wave. There are many peaks and valleys to the signal. It is only really meaningful to characterize it by it's RMS power. A very good document discussing this is found in the newsletter from Rohde & Schwarz, called "News from Rohde & Schwarz. See issue #172, pages 44-48, "Measurements on MPEG2 and DVB-T Signals".



oscilloscope display of DVB-T signal - R&S

The Crest Factor is an important concern for digital signals. It is the ratio of the peak to the rms value. It tells you the max. amount of drive to which an rf amplifier can be used in a DVB-T transmitter and still remain in the linear range without signal limiting. While theoretically the crest factor could be very high, R&S says "*Investigations have shown that for a crest factor of approximately 13dB there is no appreciable impairment of the bit error rate (BER)*." R&S also says -- *"For economical reasons, the crest factor in DVB-T transmitters is usually limited to 10 or 11dB."* Thus for a transmitter capable of putting out 100 Watts (PEP), allowing for a crest factor of 10dB, it's DVB-T, rms power would be 10 Watts (rms).

R&S goes on further to state --- "*Thermal power sensors supply the most accurate results for measuring the power of a DVB-T transmitter. Plus, they can easily be calibrated by performing a highly accurate DC voltage measurement*."

The classic Hewlett-Packard model 432A is such a power meter. It uses thermistor power sensor heads. The meter has a self-balancing bridge which compares DC power to the unknown RF power.

POWER METER TESTS: I have run some test bench experiments to see what answers we might expect to get with different RF power meters. I first started out with low, milli-watt signals to do a comparison of several test instruments of mine to verify accuracy. They were an HP-8656A signal generator, an HP-432A power meter with an HP-8478B thermistor power sensor head, and a Rigol DSA-815 spectrum analyzer. I generated a 441 MHz, CW, pure sine wave with my HP-8656A signal generator and adjusted it's rf level to read exactly +5.0dBm on the HP-432A. The interconnecting cable had 0.2dB of loss and the HP signal generator was set to +5.2dBm. Thus the two agreed exactly. Then using the same cable and generator setting, I measured the CW signal on the Rigol. It's marker read +5.16dBm, i.e. 0.16dB high, but still excellent agreement. I tested the Rigol on two bandwidths of 300kHz and 30kHz and got the same result.

The next test was at high power of 3 Watts (34.77dBm) at 441 MHz with both a pure CW sine wave and also DVB-T signal. The DVB-T signal source was a Hi-Des model HV-320E modulator set to 441MHz with 6 MHz bandwidth and QPSK modulation. A KH6HTV model 70-7B, 70cm amplifier was used to amplify either the CW sine wave or the DVB-T signal to the 3 Watts (rms) power level. The power level was set and measured using the HP-432A thermistor power meter, plus a calibrated 30dB, 50 Watt, Narda 776B attenuator.

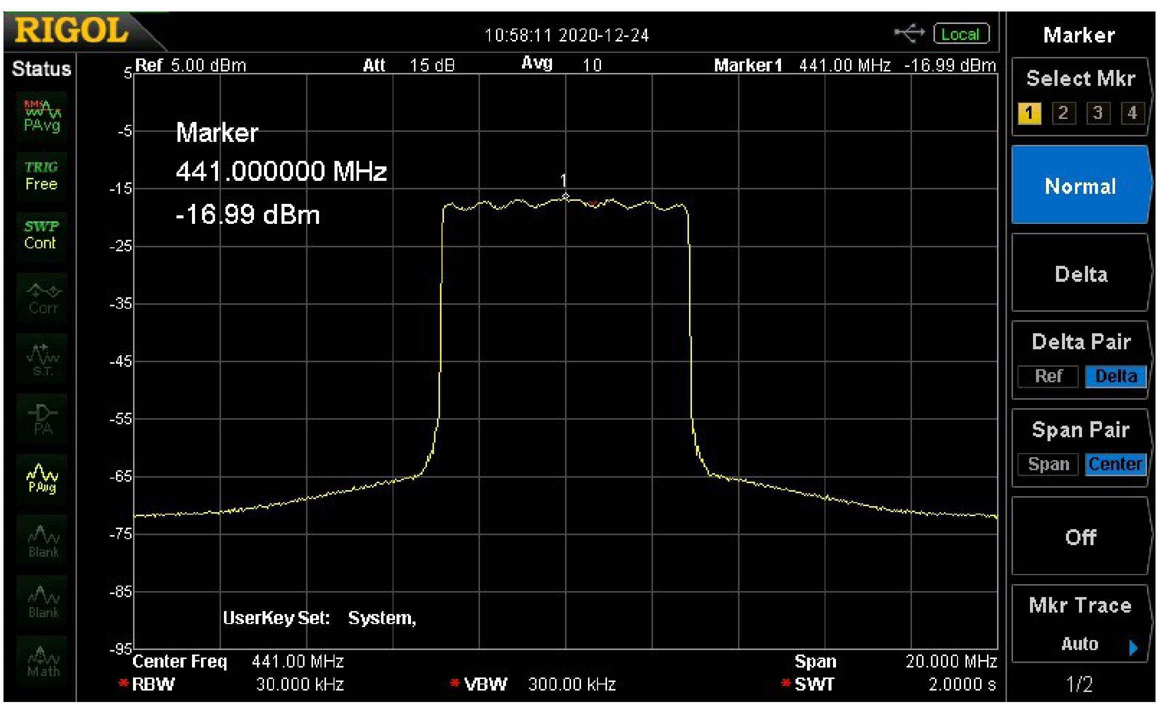
I then inserted between the amplifier and the 30dB attenuator two conventional rf power meters which use semiconductor diode detectors. The first one was an M.C. Jones, Micro-Match, 70-500MHz, in-line power meter. I also borrowed from Bill, K0RZ, a

Bird model 4300-400 with both average and peak reading capability. I used a Bird, 10 Watt, 200-500MHz power sensor in the Bird meter.

Both the Micro-Match and the Bird were quite accurate measuring the 3 Watt, CW sine wave. The Micro-Match was -0.3dB low. The Bird was only -0.1dB low. But when they were used to measure the 3 Watt DVB-T signal, both meters read too high. The Micro-Match reading was +1.3dB too high. The Bird's reading was +2.1dB too high in CW mode and +2.3dB too high in peak mode. Thus either of these meters would give erroneous, optimistic, readings of DVB-T rf power. They were obviously responding to more of the peaks in the DVB-T signal than the rms value.

SPECTRUM ANALYZER MEASUREMENT OF DVB-T POWER: Another technique to measure the power in a DVB-T signal is to use a calibrated spectrum analyzer. The analyzer should first be set-up exactly as specified by the ITU. A good reference book is "Digital Video and Audio Broadcasting Technology" by W.Fischer (an engineer for Rhode & Schwartz). I refer you in particular to chapter 21.2, "Measuring DVB-T Signals Using a Spectrum Analyzer", pages 425-428. The analyzer settings must be as follows:

Center Frequency: center of the DVB-T channel
Span: 20 MHz
Resolution Bandwidth: 30 kHz
Video Bandwidth: 300 kHz
Detector: RMS
Sweep: slow, 2 seconds
I also recommend using signal averaging of at least 10 averages



This photo shows the proper setup for measuring a DVB-T signal. The signal was direct from a Hi-Des HV-320E modulator set for 441 MHz, 6 MHz bandwidth and QPSK. The RMS power of this signal was +5.3dBm as measured with the HP-432A power meter.

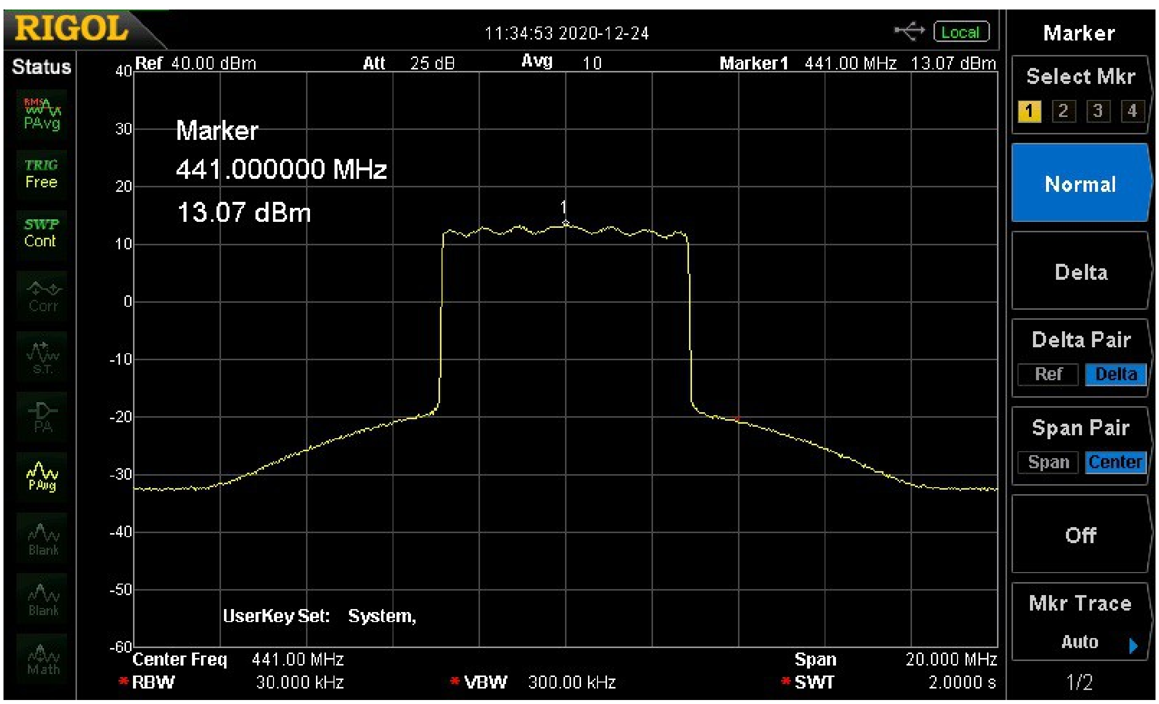
Use the analyzer's marker to measure the power at the center frequency. In this example, the value measured was -17dBm.

Thus the correction factor to be used is +5dBm - (-17dBm) ≈ +22dB

There is some uncertainty in where to make this measurement, due to the ripple in the in-channel power, plus there are some fluctuations in the observed value.

So why doesn't the analyzer measure the true +5dBm power ? The reason is the analyzer is only measuring the power in a narrow 30kHz bandwidth, while the thermistor power meter is measuring the total power spread over a 6 MHz bandwidth. An extra cost optional measurement firmware can be purchased for the analyzer which will in fact integrate the power over the entire displayed span.

The +22dB correction factor is only good for measuring 6 MHz bandwidth signals. If you are using other bandwidth signals, then you need to determine a different correction factor value.



This photo now shows doing the measurement on the 3 Watt output from the 70-7B amplifier. This was the same signal used to evaluate the Bird and Micro-Match power meters. Applying the +22dB correction factor to the above measured +13dBm, we can estimate the rf power to be about +35dBm (3.2 Watts). This technique is not as accurate as using a thermistor rf power meter, but will give close correlation.

It should be noted that another critical measurement of DVB-T transmitter is the out of channel, spectrum skirts. This is done with the same setup as shown in the above photos. The ITU spec. is to measure the skirt, shoulder, break-points ±200 kHz outside of the channel edges. For a 6 MHz bandwidth, this is ± 3.2MHz from the center frequency. On the photos above, the shoulders from the modulator are seen to be about -45dB down and for the amplifier's 3 Watt output, they are -33dB down.

(from newsletter issue #67)

DTV POWER MEASUREMENT FEEDBACK:

Hi Jim --- Thank you for the informative newsletter. I like the article about measuring DATV power. Bird makes a APM-16 wattmeter that looks similar to a model 43 that is designed for use with digital transmitter power measurements. They also have a model 5010B power sensor that is used along with DPM slugs to measure digital RF power. We had to change over to the new meters when we switched to DTV several years ago.

Mike, WA6SVT

BIRD WATTMETER: The classical Bird wattmeter most hams are familiar with is the model 43 which was designed over 60 years ago. --- From the Bird web site www.birdrf.com " The APM-16 RF Wattmeter is designed to keep pace with the ever growing complexity of digitally-based communication systems. Bird's Model 43 and most other wattmeters available today were designed to measure power of constant amplitude, sinusoidal waveforms.

APM-16

Modern wireless communication systems can use a variety of digital techniques to combine many voice data channels into a complex, composite RF signal. Measurement of such signals with a conventional wattmeter may yield unacceptable errors.
The APM-16 employs active circuitry to deliver accuracy of ±5% for multiple-access technologies such as CDMA, TDMA, FDMA and other digitally-encoded communication systems. The APM-16 is equally effective for measuring RF power in conventional analog systems. It uses APM-series plug-in elements to cover a wide range of frequency and power levels."

(from newsletter issue #70)

DATV RF Power Measurement --- This is an add-on to my article in the Jan. 2021 issue #66 on measuring DATV power. A power meter that was omitted was the IC log power detector from Analog Devices, their AD8318. It is specified to operate from 1MHz to 8GHz, over a 70dB range. It has a spec of high accuracy (±1dB) from -50dBm to 0dBm up to 6GHz. I reviewed a Chinese pc board AD8318 meter in the Dec. 2019, issue #29, of this newsletter. In that review, I reported -- *"The AD power meter read the DTV power about -2dB low."*