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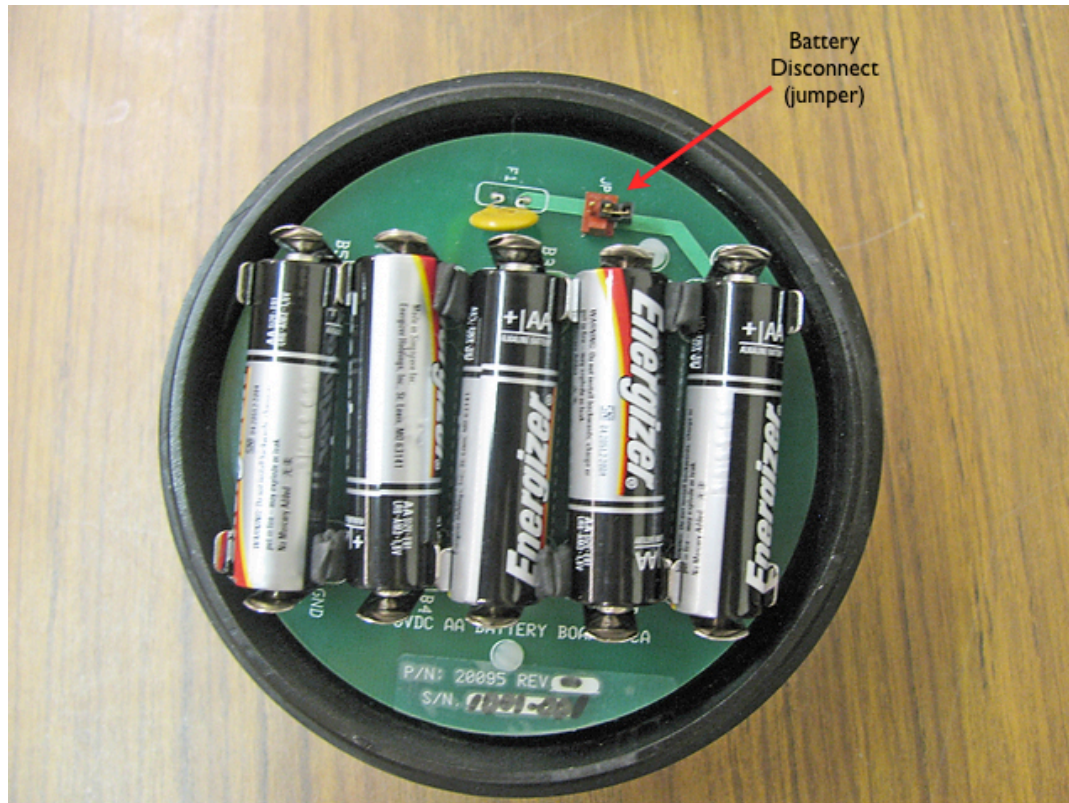
### REVIEW - AET DRFS HARMONIC COMB GENERATOR



*Fig. 1 - AET model DRFS comb generator.*

Harmonic comb generators are designed to produce fixed harmonics over a wide range of frequencies. Generally, the harmonics are fairly stable in frequency and temperature, therefore, they may be used as standards for verifying radiated emissions measurement systems in anechoic chambers or on open area test sites (OATS). There are many other uses for these generators as I have discussed in an article in the January 1991 issue of RF Design Magazine and now in my various EMC seminars. In this article, I'd like to review a low-cost battery-powered comb generator recently available from Applied Electromagnetic Technology (AET) for \$2995. More information may be found on their Web site: [www.appliedemtech.com](http://www.appliedemtech.com). This generator may be adjusted with a

recessed rotary switch, to 10, 64, 100 and 133 MHz comb frequencies. Harmonic frequencies are useful well into the GHz. The company also makes spherical models, simulating a point-source, specifically for verification of chambers and OATS ranges. These may be easily configured for both horizontal and vertical polarization. I received the DRFS model for review.



*Fig. 2 - DRFS generator with lower case unscrewed to reveal the five AA cells. There is a small jumper (upper-right) that serves as a battery disconnect switch in case the unit is stored for lengthy periods.*

When using the comb generator as a standard source for use in verifying radiated emissions measurement systems, the generator will require an antenna (not supplied). While it was primarily designed to be used with horn antennas, which may be adjusted for either horizontal or vertical polarization, a short vertical monopole may also be used - as was the case for this review. The antenna selected was a short monopole "rubber duck" antenna made by Yaesu. However, any short monopole (including home made) should work satisfactorily.

## TESTS PERFORMED

Several performance verification tests were performed on this unit - direct measurements, radiated measurements and temperature tests to determine frequency and amplitude stability. The equipment used was an Agilent E4443A PSA Spectrum Analyzer configured as an EMI receiver. For

the temperature tests, I used an HP 8591EM EMC Analyzer. The temperature chamber was an industrial Thermotron configured in manual mode.

## **DIRECT MEASUREMENTS**

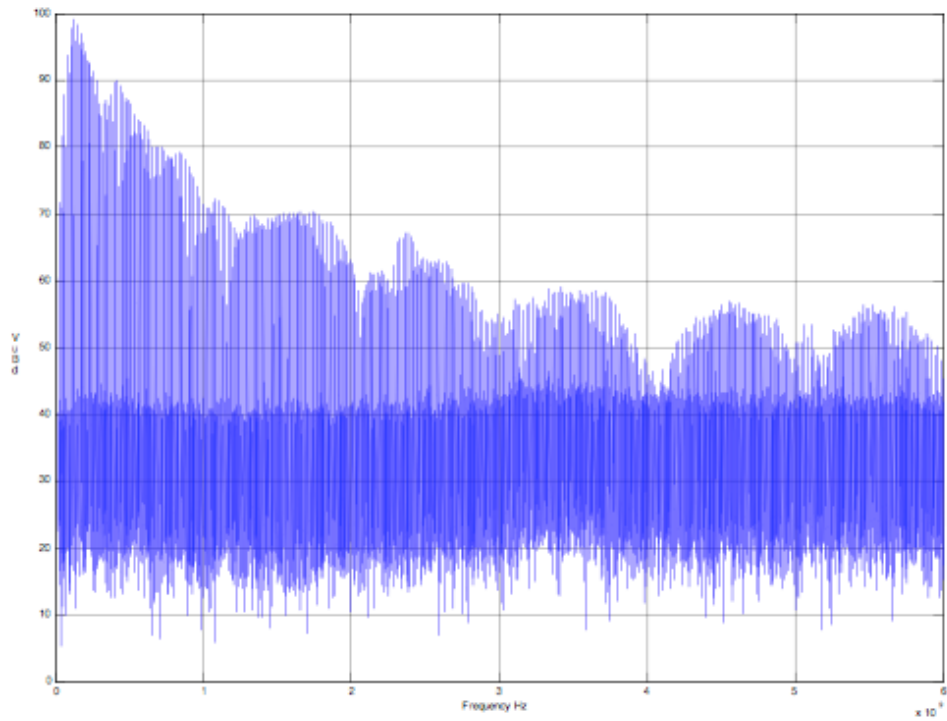
The DRFS was connected directly to the EMI receiver and tested at each clock frequency (10, 64, 100 and 133 MHz - only 10 and 100 MHz shown here for brevity). I was primarily looking for the upper harmonic frequency and amplitude roll-off characteristics, but the DRFS exceeded the upper limit of 6 GHz for the EMI receiver; even at a clock frequency of 10 MHz! The roll-off was 30 dB/decade from 10 to 1000 MHz, tapering off to 3 to 8 dB per decade up through 6 GHz. The harmonic amplitudes are very high, ranging from near 100 dBuV at 10 MHz, to 70 dBuV at 1 GHz. Amplitudes from 1 to 6 GHz, range from 50 to 60 dBuV - plenty of output for most testing.



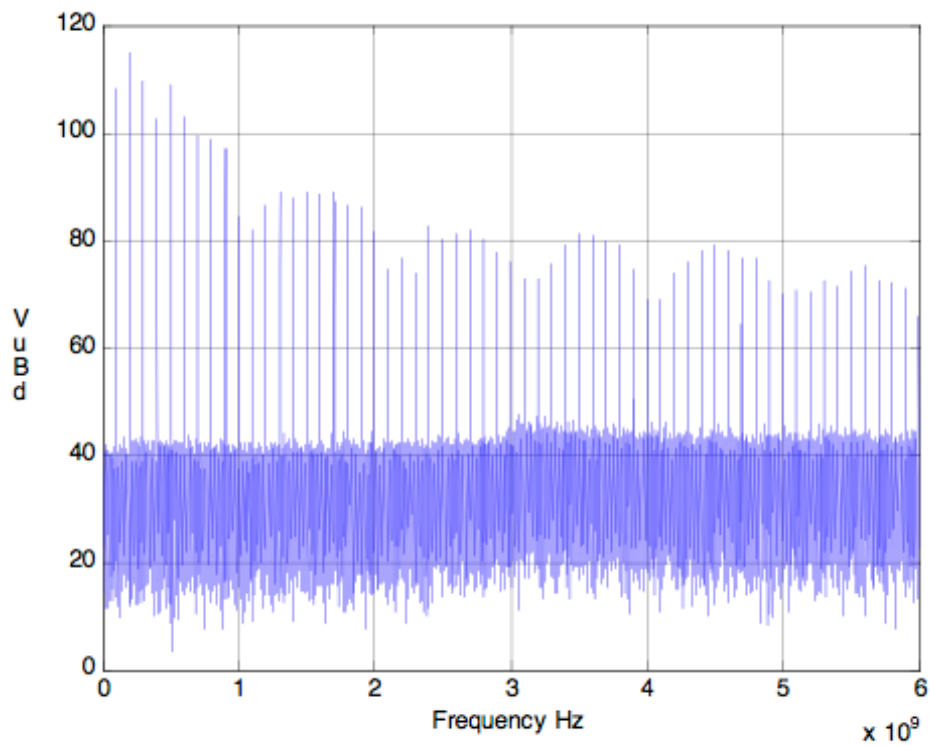
**Fig. 3** - DRFS  
*generator connected with a 1m high-quality coax cable directly to the Agilent EMI receiver.*

Following are the direct measurements for clock frequencies of 10 and 100 MHz (other clock frequencies not included for brevity):

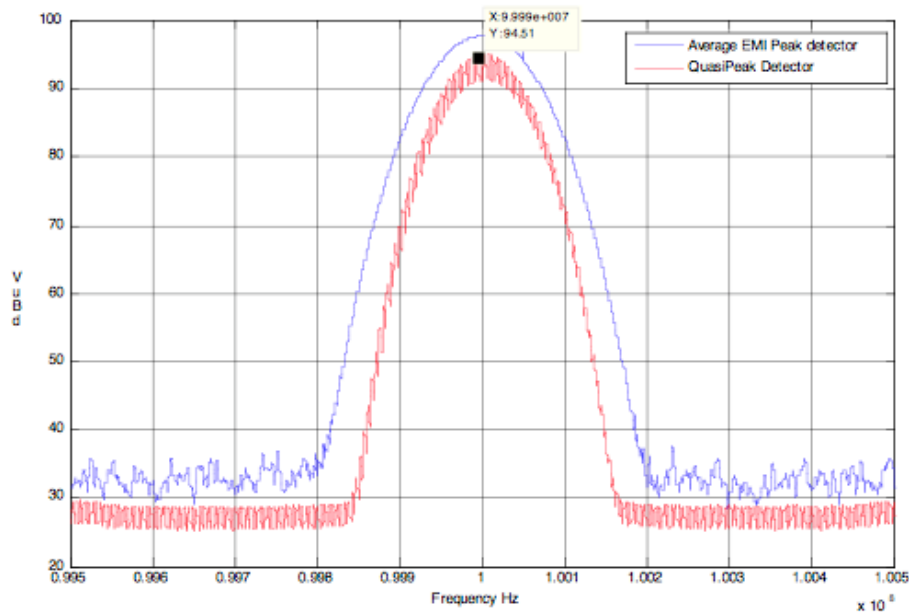




*Fig. 4 - Direct measurement with 10 MHz clock.*



*Fig. 5 - Direct measurement with 100 MHz clock.*



**Fig. 6 - Direct measurement comparing peak versus quasi-peak measurement at 100 MHz.**

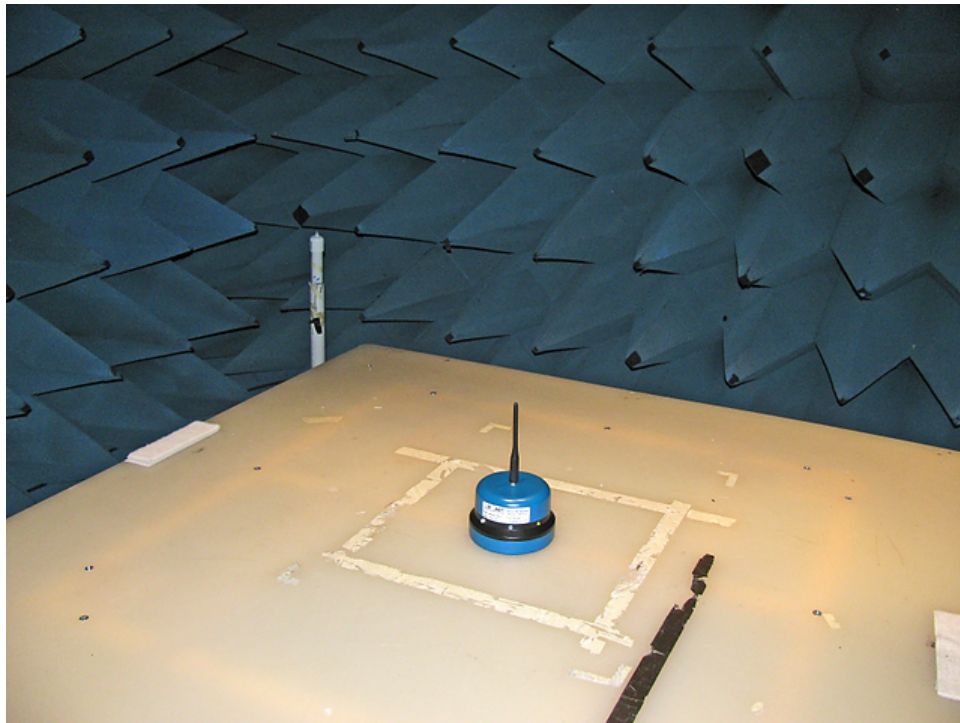
It's interesting to note that at 10 and 100 MHz, the sine-x/x envelope has minimums at even multiples of 1 GHz, as you might expect. If these particular frequencies are critical, more amplitude may be achieved by using clock frequencies of 64 or 133 MHz. The DRFS amplitudes and upper frequency exceed anything else I've reviewed by a long shot - including my own comb generator design.

If you wish to verify your quasi-peak measurement, just turn on the Pulse Mode (turns the harmonics on/off at 2 Hz) and we see in Fig. 6 that the difference between peak and quasi-peak is approximately 3 dB, as expected.

## **RADIATED EMISSION MEASUREMENTS**

Next, the DRFS was placed on the turntable of a 3m fully-anechoic chamber and the harmonics were measured from 30 to 1000 MHz (the limit of the test software). A short monopole antenna (Yaesu) was used as the transmitting element. The turntable was rotated 360 degrees during the test, which allowed us to record the amplitude versus azimuth, as well.

Two plots were recorded: amplitude versus frequency (2D) and amplitude versus frequency versus azimuth (3D). Custom MatLab software was used to measure and capture the data.



*Fig. 7 - DRFS placed on the turntable in a 3m fully-anechoic chamber.*

It's interesting to note that despite the lack of counterpoise in the DRFS case (it's all plastic) the polar plot of amplitude versus azimuth is fairly well-behaved at the upper frequencies. This can be easily observed as dips along the azimuth axis at each harmonic frequency starting about 800 MHz and up. Based on this, I would say that, at least for frequencies to 1 GHz, no counterpoise is really required. This may not be the case above 1 GHz.

The maximum amplitude point around 450 MHz indicates the resonant point of the antenna. The response falls off at the high frequency end due to both inefficiencies in the antenna and the fact the output of the comb generator is gradually falling off.

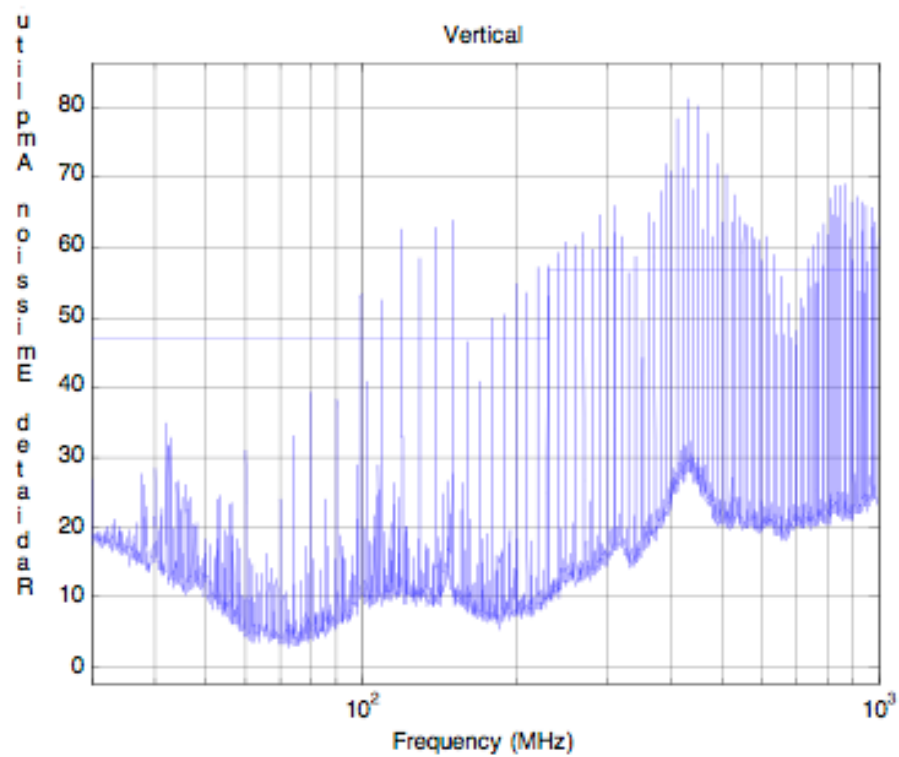


Fig. 8 - DRFS radiated measurement in a 3m fully-anechoic chamber (10 MHz).

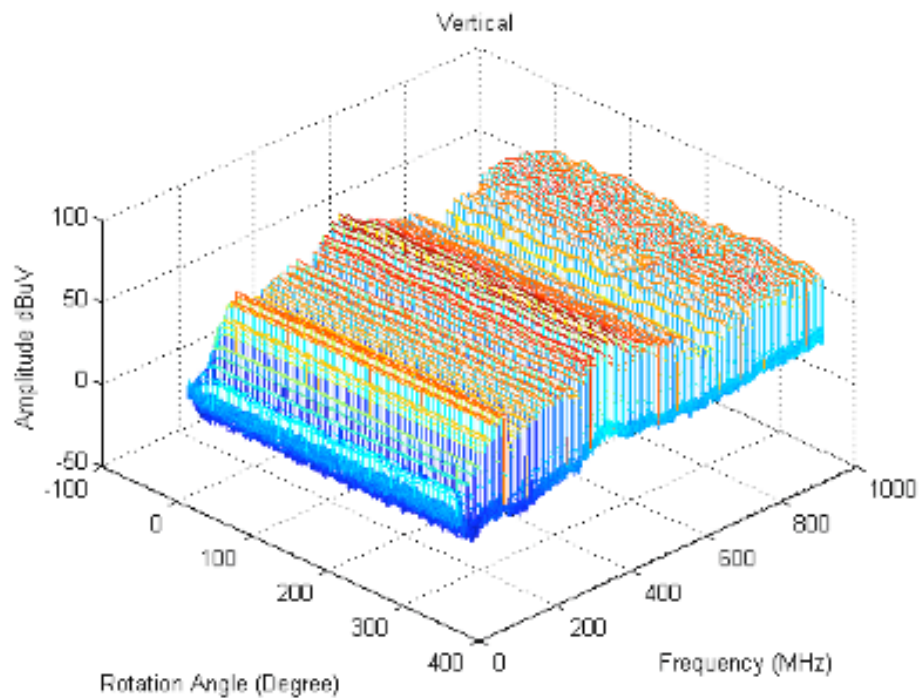


Fig. 9 - DRFS radiated measurement in a 3m fully-anechoic chamber (10 MHz).

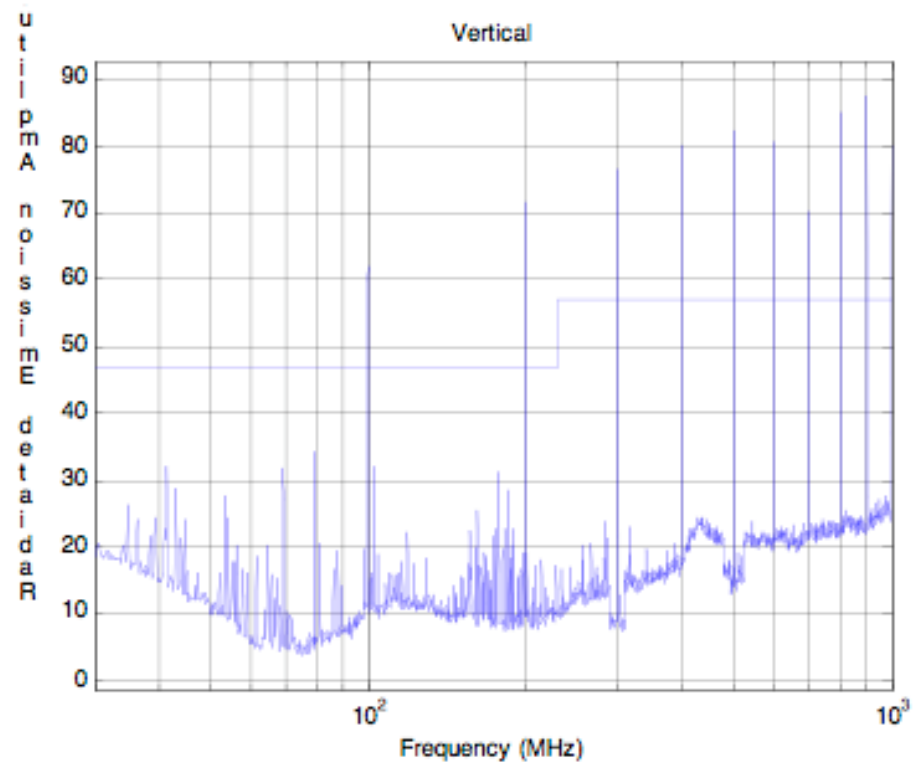


Fig. 10 - DRFS radiated measurement in a 3m fully-anechoic chamber (100 MHz).

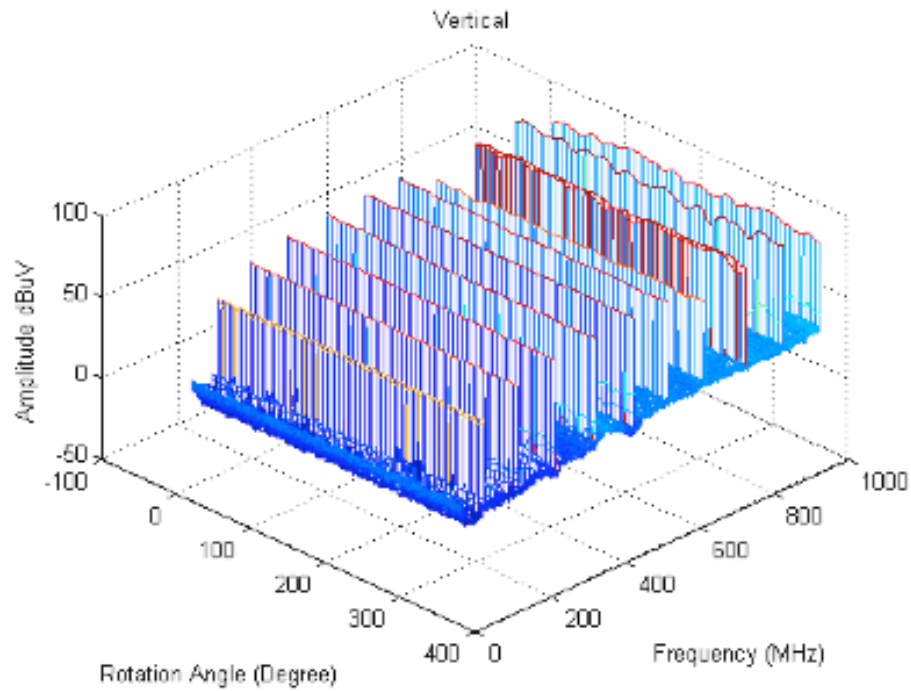


Fig. 11 - DRFS radiated measurement in a 3m fully-anechoic chamber (100 MHz).



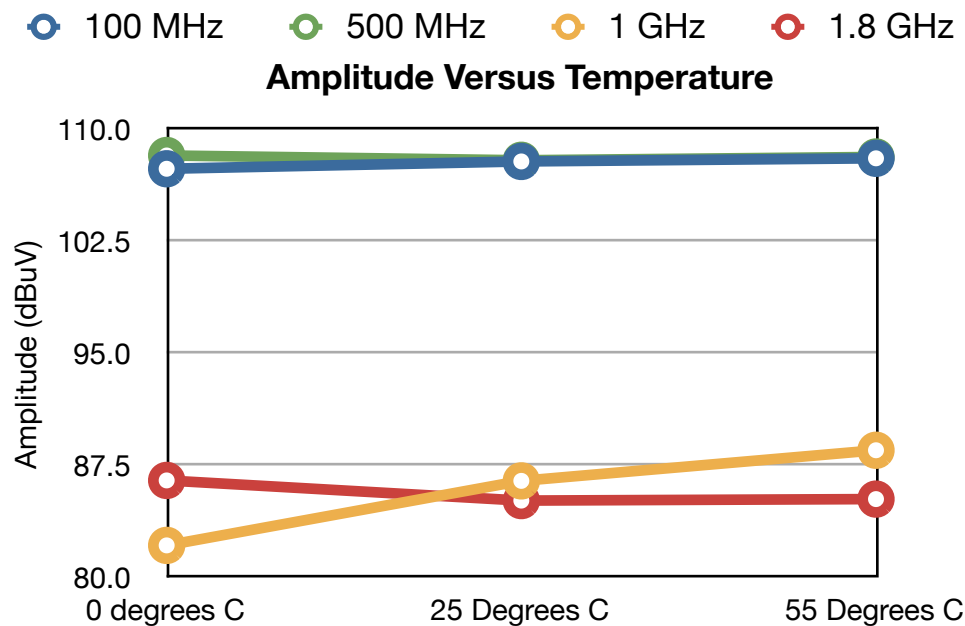
## TEMPERATURE TESTS

The DRFS was then placed into an industrial Thermotron temperature chamber and tested at the normal (non-military) operating temperature range of 0, 25 and 55 degrees Celsius. It was directly connected to an HP 8591EM EMC Analyzer with temperature-compensated master clock. The chamber was set to each temperature manually and the unit was allowed to stabilize for 15 minutes for each temperature step based on its estimated thermal mass. Tests were conducted at 100, 500, 1000 and 1800 MHz (limit of the receiver). The receiver display was set to video averaging mode to reduce the amplitude variation with sweep. A span of 2 MHz was used for each frequency and a marker was placed at the top of the harmonic to record both frequency and amplitude. Multiple readings were taken and then averaged to get the most accurate measurement of amplitude and frequency for each temperature step.



*Fig. 12 - DRFS temperature measurement using a Thermotron chamber.*

*The primary reason I wanted to characterize the temperature properties of the DRFS is that it could be used to either validate an open area test site (OATS) or it could be used to compare site-to-site variations. In Colorado, it's not unusual to do site validation or comparison testing at outdoor OATS during these sort of temperature extremes.*



*Fig. 13 - DRFS amplitude measurement versus temperature.*

In the case of the DRFS, 100 and 500 MHz were stable with temperature variation and could be used as an accurate reference. 1800 MHz was also stable enough, varying only 0.6 dB at zero degrees C. The 1000 MHz harmonic, however, had a mind of its own, increasing by 2 dB at 55 degrees and decreasing by 4.6 dB at zero degrees from nominal room temperature. I'm not sure I can explain why 1000 and 1800 should be so different from each other, as they are not that far apart in frequency.

There was one other interesting anomaly at 1800 MHz. After about 20 minutes at zero degrees C, sidebands at +/- 0.5 MHz started to appear, growing gradually to the point where I decided to terminate the test, as I didn't want to "kill" the unit I was evaluating. After discussing this with the designer, the probable conclusion was that the internal amplifiers were being overdriven slightly due to the greater efficiencies at cold temperatures. Because the sidebands were well down (-37 dB) from the main harmonic, this should not be much cause for concern. Hopefully, AET will be looking into this.

	Ampl (dBuV)		
Freq (MHz)	0 degrees C	25 Degrees C	55 Degrees C
100	107.37	107.86	108.07
500	108.26	107.94	108.16
1000	82.15	86.47	88.52
1800	86.5	85.15	85.25

*Fig. 14 - DRFS amplitude measurement versus temperature (table).*

Frequency, on the other hand, was perfectly stable and adequate for calibration purposes, especially at frequencies of 1000 MHz and below.

Freq (MHz)	Frequency (MHz)		
	0 degrees C	25 Degrees C	55 Degrees C
100	100	100	100
500	500	500	500
1000	999.98	999.98	999.98
1800	1799.97	1799.5	1799.95

*Fig. 15 - DRFS frequency measurement versus temperature (table).*

## SUMMARY

The AET model DRFS harmonic comb generator is a small highly portable generator that can output robust harmonics at least through 6 GHz and likely much higher. The harmonic amplitudes are much greater than the FCC or CISPR Class A or B limits as used with the short monopole antenna, as can be seen in the radiated plots above. It was designed to either validate the measurement system in open area test sites (OATS) or anechoic chambers. It may also be used for site-to-site correlation studies. It may also be directly connected to antennas, such as a horn antenna. Because there was minimal amplitude change versus azimuth, so it may be used to accurately compare test ranges by including any variation effects for user test software or procedures.

Because it is battery-powered, cable radiation will never be an issue. Specified battery life is 8 hours with the standard "AA" alkaline battery pack and 4 hours with the optional "AAA" NiMH battery pack (not tested). I wish the DRFS used four cells, rather than five, as this is an odd number and requires the user to typically break open a second pack. Also, the "AAA" NiMH cells are not commonly available at the nearest retail outlet. I'd also like to see a small PC board-mount on/off switch used inside the battery compartment to shut off the apparent "dark current" when the unit is not to be used for a length of time.. The small jumpers seem too easy to lose. Hopefully, production units will also have the controls labeled. Otherwise, the unit is compact and easily used.

The unit is cleverly designed into a small round plastic enclosure, but could be susceptible to breakage if dropped. I'd take special care during shipping and handling. Pelican Products makes a hard waterproof case that would protect this perfectly (model 1300, [www.pelican.com](http://www.pelican.com)).

Both direct and radiated measurements proved accurate in frequency and provided plenty of punch in harmonic levels - much better than earlier designs. The switchable clock frequency is a real plus, as there may not be cases where such a fine frequency spectrum (10 MHz, for example) is really required. This might include validation measurements, where the user may only wish to measure a few harmonics to have confidence of their test range. Because there are sin-x/x dips at 1 GHz steps (at 10 and 100 MHz), the user may switch to 64 or 133 MHz steps in order to fill in the frequencies around these points. This would also be valuable as a frequency source for demo purposes during EMC seminars.

*I do have some concerns at low temperature operation, as some of the harmonic amplitudes seemed to vary considerably (1 GHz, for example). Yet there were other harmonics that were very stable. This may prove worthy for AET to look into. As it is, I would not use the DRFS to do outdoor site comparisons in cold temperatures. However, it would be perfectly usable in any indoor chamber. Also, while not a deal-killer, the increasing sidebands at 1.8 GHz (and potentially others) are of interest, but probably not worth worrying about, since they are well below the fundamental amplitude. Again, maybe something for AET to look at down the road.*

*If you're looking for a low-cost multi-frequency comb generator that reaches up into the GHz region, look no further - this may be all you need. Recommended.*

*Acknowledgment: I'd like to thank Dr. Kuifeng Hu, Sr. EMC Engineer, Agilent Technologies, for his assistance making these measurements and Dr. Bruce Archambeault of AET for the use of the DRFS.*