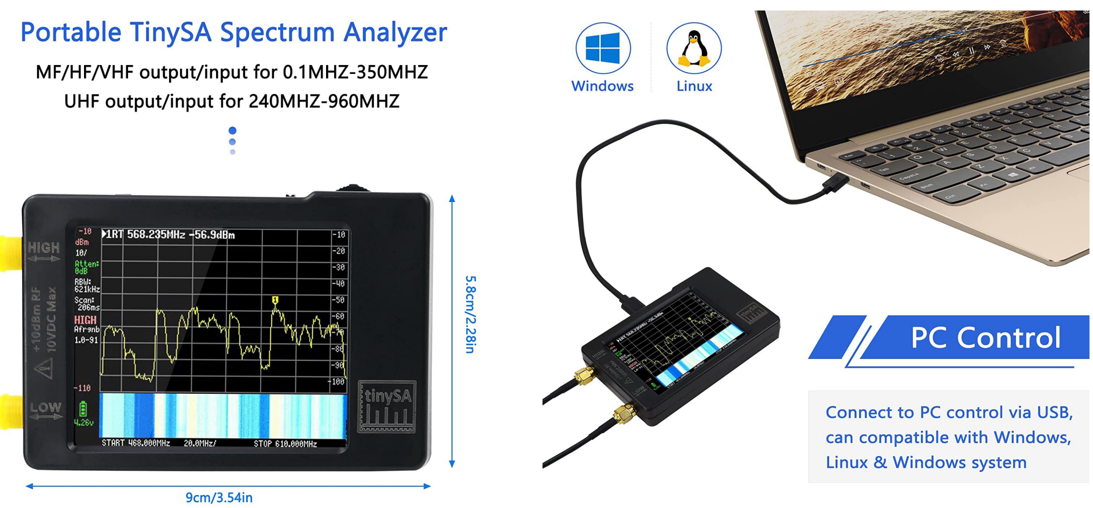
Application Note AN-62

web = www.kh6htv.com email = kh6htv@arrl.net

TinySA - an Inexpensive Test Instrument for Digital Transmitters

Jim Andrews, KH6HTV



The success of the **NanoVNA** led the folks who developed it to follow it with the companion **TinySA**, a Spectrum Analyzer, with equally impressive performance. While it is billed as a spectrum analyzer, it is also an RF signal generator. The basic performance covers from 100 kHz to 350 MHz. It can also be used up to 960 MHz but with poorer performance. The price is astonishing low for what you get in this tiny package. I got mine from Amazon for about $70 with next day delivery.

The best place to go for information, specs., instruction manual, PC program, etc. is the TinySA wiki web site: (www.tinysa.org/wiki/) I highly recommend you download the ***tinySA-App*** for your Windows PC. See Fig. 3 on the next page. It greatly increases the ease of use and capabilities of this fantastic instrument. The spectrum plots in this app. note were obtained using the PC. The wiki site is quick to point out that it does not have all of the capabilities of name brand spectrum analyzers and they do list the limitations you need to be aware of. But the price is right ! They also caution you to be careful and not purchase imitation "clones" as they have inferior performance.

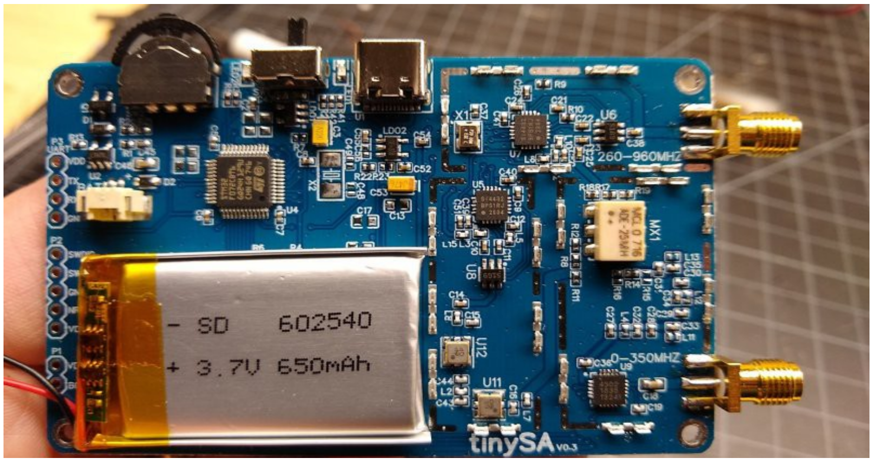


Fig. 2 A peek inside of the TinySA, Spectrum Analyzer

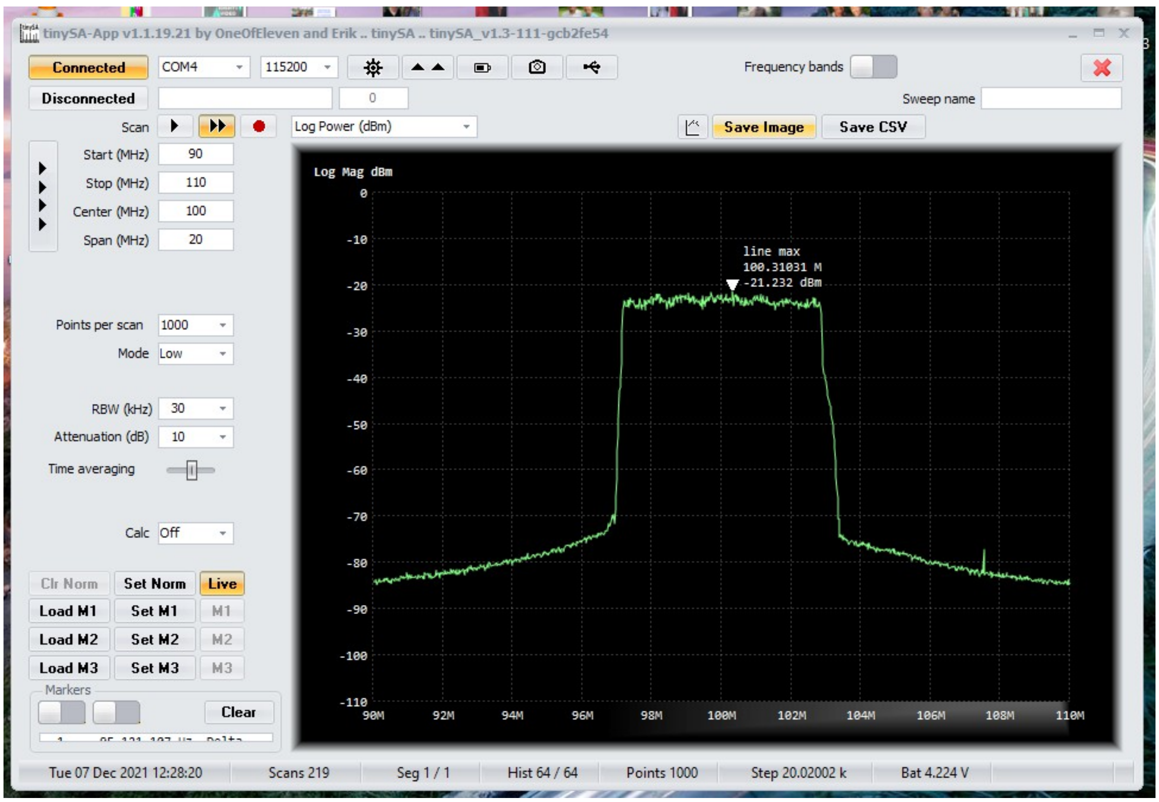


Fig. 3 This is what the TinySA-App control screen looks like on a Windows PC.

Googling "TinySA", you will find a lot of reviews of it's performance by hams. These reviews mainly deal with classical sine wave performance, with modulations such as AM, FM, etc. The focus of KH6HTV Video is on Amateur Television (ATV) and in particular Digital Amateur Television (DATV). So it was natural for me to ask, how well can I measure the spectral performance of a digital TV transmitter. The rest of this application note will address this.

ITU Specification: The ITU has specified how the spectrum of a digital TV signal should be measured. The analyzer settings, per the ITU, are: center frequency = DVB-T channel center frequency, Span = 20 MHz, Resolution Bandwidth = 30kHz, Video Bandwidth = 300kHz, Sweep Time = 2 seconds, Detector = RMS, Signal Averaging = 10. The shoulder attenuation is measured at ±200kHz beyond the channel edges, i.e. ±3.2MHz from center frequency for a 6 MHz wide channel. For further details, I refer the reader to the DTV "Bible" --- *"Digital Video and Audio Broadcasting Technology*", by Rhode & Schwarz engineer, Walter Fisher, page 426. [1]

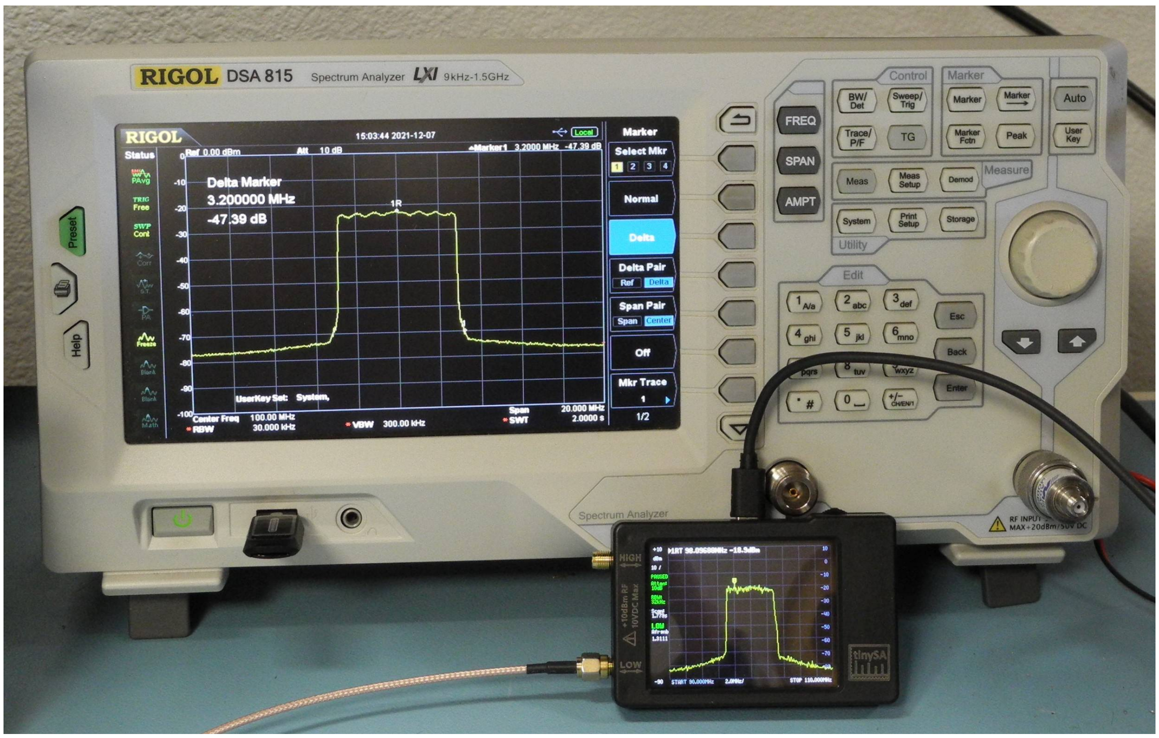


Fig. 4 The TinySA and the Rigol DSA-815 Spectrum Analyzers measuring a DTV signal.

Reference for Comparison: I have been using now for several years a high quality spectrum analyzer to characterize my DTV amplifiers and transmitters. It is a Rigol model DSA-815, 1500 MHz spectrum analyzer with a built-in tracking generator. It cost about $1,500. This app. note will compare measurements made with the Rigol against the TinySA. The DTV signal source I used is a Hi-Des model HV-320E, DVB-T modulator. I set up the modulator to generate a 6 MHz bandwidth, QPSK signal of 0dBm signal strength. Fig. 5 shows this signal measured on the Rigol with the ITU settings. The center frequency was 100 MHz. The HV-320E covers frequencies up to 2.6GHz with an identical spectrum. Note the DTV energy is spread over a 6 MHz bandwidth. The analyzer's detector bandwidth is set to 30kHz and is only measuring the power in this narrow bandwidth. Thus the power level of the flat top shown in Fig. 5 is about -22dBm, but spread over 6 MHz. Thus when using 30 kHz BW for a 6 MHz BW DTV signal, an approximate power measurement can be made by reading the power at the center of the channel and then applying a +22dB correction factor.

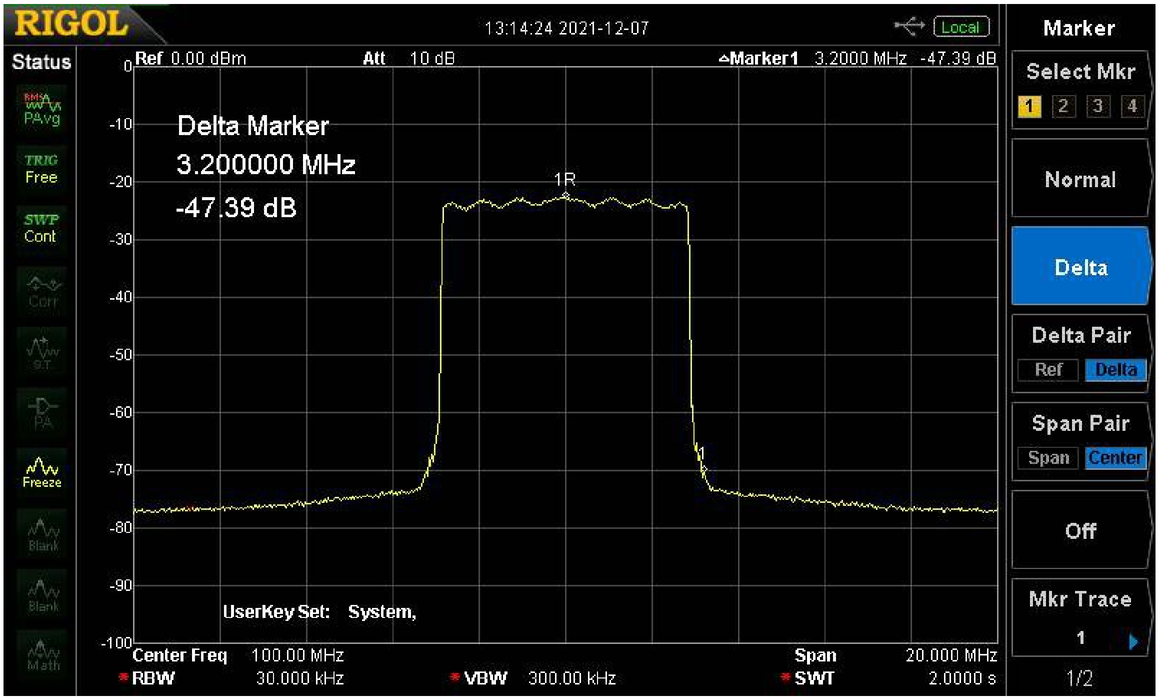


Fig. 5 HV-320E spectrum as measured on the Rigol DSA-815. Pin = 0dBm. Center frequency = 100 MHz, 20 MHz span, 30kHz resolution bandwidth, 300kHz video bandwidth, 2 second sweep time, RMS detector, 10 averages, 10dB/div & 2MHz/div.

MEASUREMENTS with TinySA: The first measurement performed with the TinySA was with the same HV-320E signal as shown above in Fig. 4, but at a higher, 70cm frequency of 435 MHz. The DTV signal was input to the HIGH port of the TinySA and it was put in the UHF mode. The TinySA was set to duplicate as close as possible the same settings used on the Rigol SA. The center frequency was set to 435MHz with a span of 20 MHz. The TinySA tries to always use "Auto" to set up bandwidth and input attenuation. I forced it into manual mode via the PC program. I set the bandwidth to 30 kHz and input attenuation to 0 dB. Data points were set to 1000, and signal averaging was set to 8.

In the UHF mode, the TinySA does not have a good input attenuator, so a 10dB SMA attenuator was placed on it's SMA input. A -10dB correction factor was entered in the "Gain" menu to account for the attenuator in the vertical calibration scale factor.

Fig. 6 below shows the result. This does not compare favorably with that seen on the Rigol, Fig. 5. The level of the flat top is approximately correct. But notice the horrible out of channel skirts on the spectrum. These are false artifacts not present in the DTV signal. They are generated by severe non-linearity in the TinySA's UHF circuit. This result is obviously unacceptable.

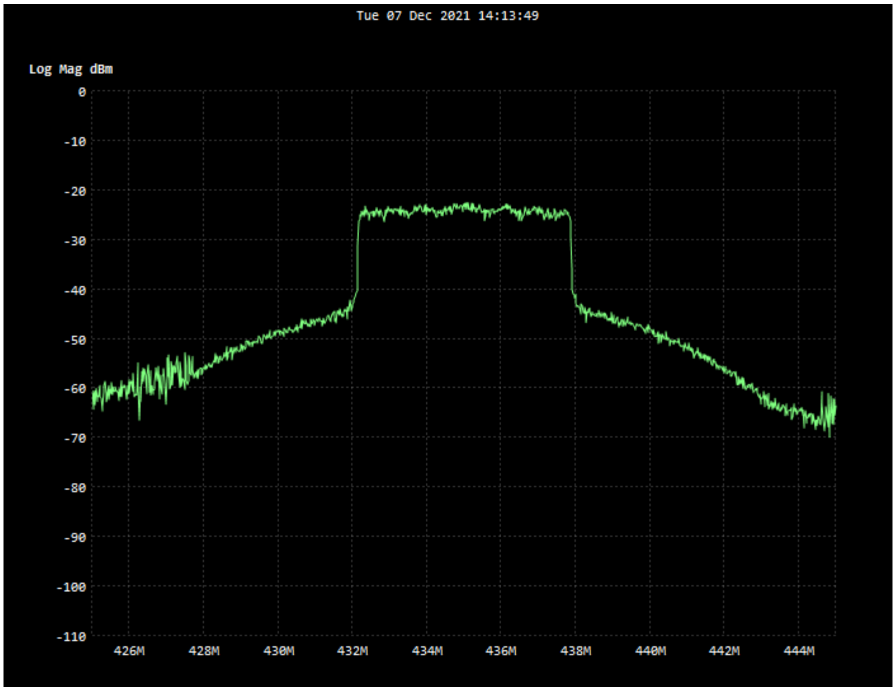


Fig. 6 435MHz, 6 MHz BW, 0dBm DTV signal measured directly on the TinySA, using the HIGH, UHF input.

The next test was to repeat the measurement but instead use the LOW input which covers MF, HF, & VHF bands (0.1 - 350 MHz). The measurement was done at 100 MHz. Fig. 7 below is the result. This now compares very favorably with the Rigol measurement, Fig. 5. The shoulder break points now at about the same level of > -45dB.

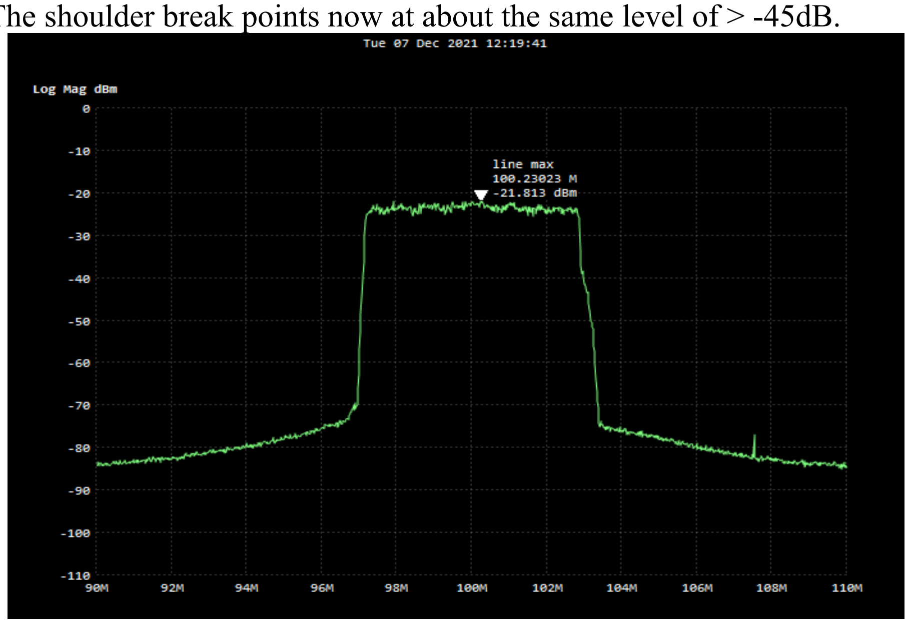


Fig. 7 100 MHz, 6 MHz BW, 0dBm DTV signal measured directly on the TinySA using the LOW, VHF input.

CONCLUSION: The TinySA will make accurate DTV spectrum measurements if the LOW, VHF input is used. The HIGH, UHF input should not be used.

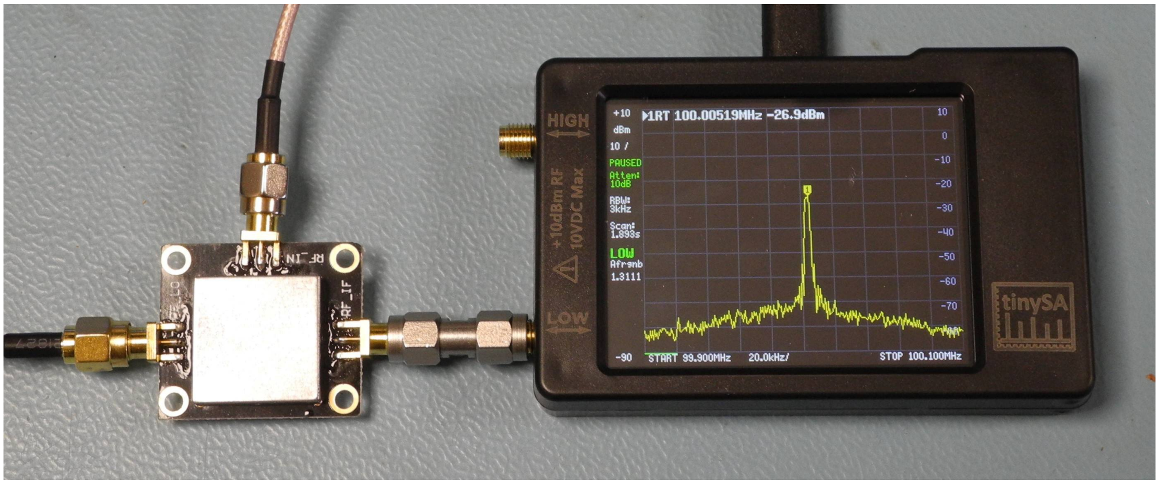


Fig. 8 The better way to measure frequencies higher than 350 MHz

MIXER MEASUREMENTS: So to be able to measure our 70cm and higher frequency DTV transmitters, we need to instead go to a mixer scheme. Low cost mixers are available on-line these days. Fig 8 above shows a $15, SMA mixer using a Mini-Circuits ADE-25MH double balanced diode mixer. The RF & LO are rated for 5 MHz to 2.5 GHz. The IF is rated for 5 MHz to 1.5 GHz. The LO requires +13dBm drive. I measured 7dB RF to IF down conversion loss. The TinySA vertical scale factor can be corrected for this loss by entering -7dB in the "Gain" menu.

There are quite a few, low cost choices for the LO. One possibility is to simply use another TinySA, not as a spectrum analyzer, but as a signal generator. Put in the HIGH-UHF OUT mode, it's frequency is programmable from 240 MHz to 960MHz. The output is a square wave. The max. output level per the menu is +16dBm. I actually measured it to be from +16 to +18dBm. The programmable level control was not very accurate. The LOW, MF-HF-VHF, signal generator is more accurate.

I ran some experiments with this mixer scheme to determine if accurate DTV measurements could be performed on the 70cm and 23cm bands. I used an IF of 100MHz for the 70cm band and set the LO to 335 MHz for an RF input of 435 MHz. For the 23cm band, I set the LO to the TinySA max. limit of 960 MHz. Thus for an RF input of 1243 MHz, the IF out was 283 MHz, which still fell with the LOW-VHF mode.

Fig. 9 shows the result of a test using a 23cm, 1243MHz, DVB-T signal. The RF power level was adjusted over a wide range to determine the limits of linearity. It shows the power stepped from 0dBm, to -3dBm to -5dBm. Note the improved skirts as the RF input power level is dropped. The conclusion drawn was that the input power should be kept below -3dBm and preferably below -5dBm. This experiment was also performed at 70cm and I obtained identical results.

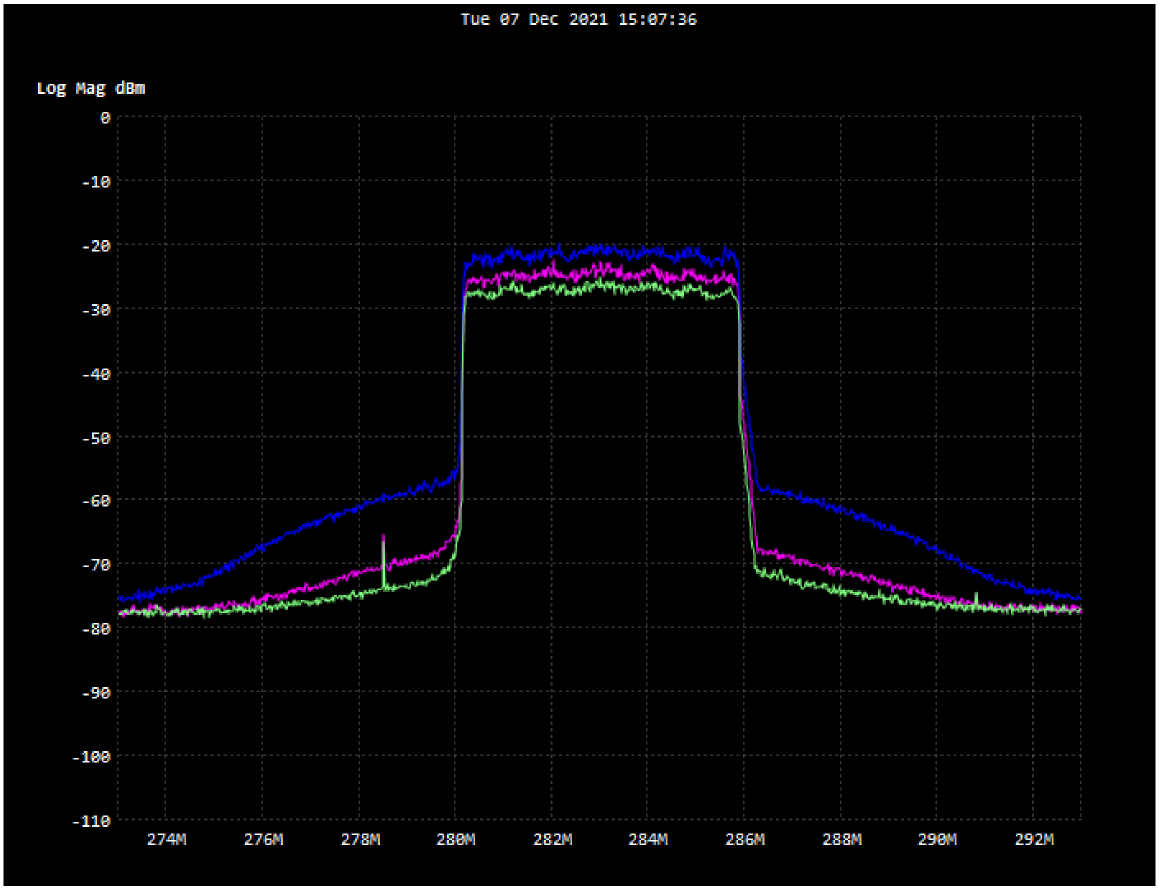


Fig 9 Test of the TinySa plus mixer to measure a 23cm, 1243MHz, DVB-T signal. RF input power level stepped to demonstrate non-linear compression at high input power. Blue trace is 0dBm, Magenta trace is -3dBm. Green trace is -5dBm.

EXAMPLE of USE: Fig. 10 below shows an example of using the TinySA with an external LO and mixer to measure the spectrum performance of a 70cm, RF linear power amplifier. The amplifier's output power was +35dBm (3.2 Watts). A high power, 30dB attenuator followed by a 10dB attenuator was used to drop the signal level to the mixer down to about -5dBm.

You might ask why the out of channel spectrum is higher than that of the modulator input signal, Figs 5 & 7 ? Nonlinearities in linear high power amplifiers generate these IMD spurious signals (noise) which land outside of the desired 6 MHz channel band edges. For DVB-T transmitters, Fisher [1], on pages 446-448 states that they have found that acceptable performance for commercial broadcast DVB-T transmitters, without degrading the S/N of the digital signal is obtained by driving the final amplifier until the out of channel spectrum shoulder break-point reaches -28 dB below the in channel power level. Then for their R&S transmitters, they then add digital pre-distortion as equalization. This buys them another 10 dB, driving the shoulder down to -38 dB. Then the output of the final power amplifier is passed through a channel mask, band-pass filter which drops the shoulder even further to -52 dB, thus meeting govt. regulations.

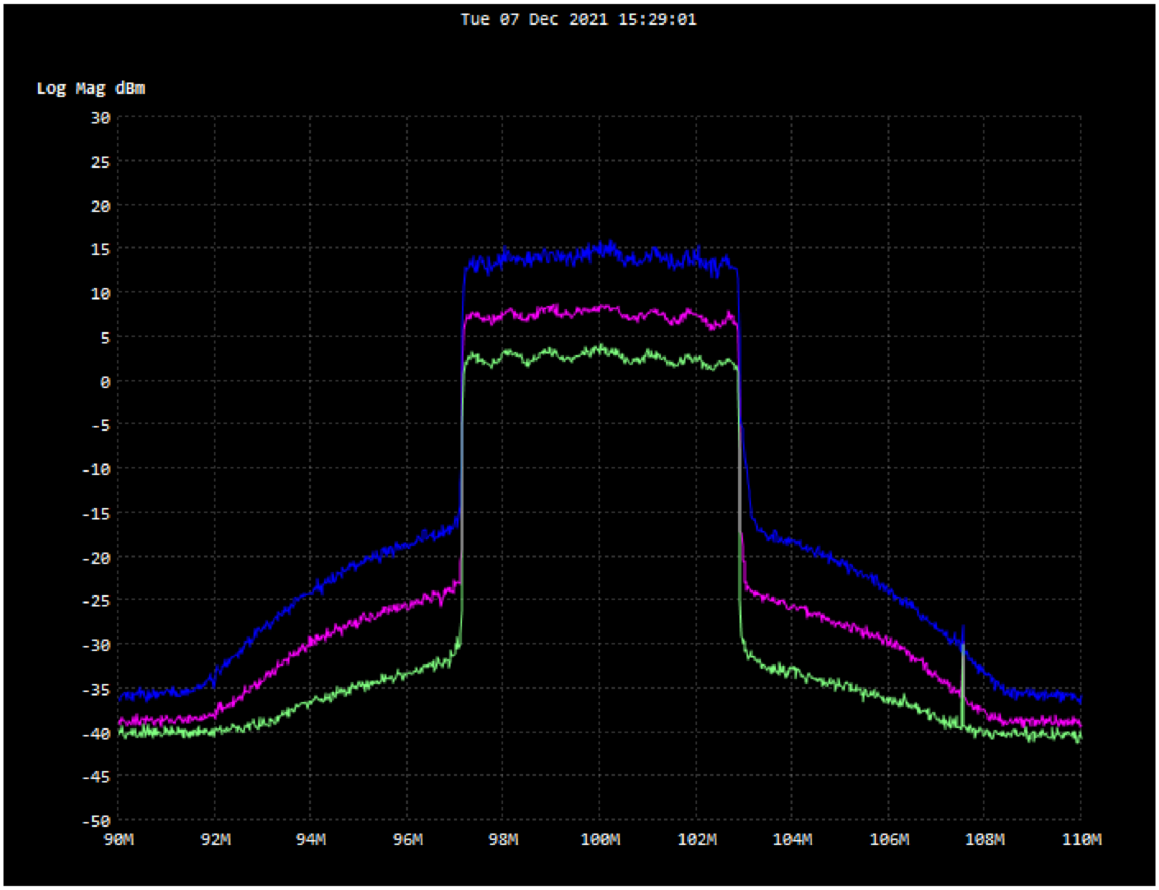


Fig. 10 TinySA measurement of a KH6HTV Video model 70-7B Amplifier. Center frequency is 435 MHz. 5dB/div & 2MHz/div. The amplifier's output was adjusted from High to Medium to Low in -5dB steps. Blue trace is +35dBm, magenta trace is +30dBm and green trace is +26dBm.

For our ham radio, DVB-T transmitters, I have found that a good compromise trade-off between maximizing the RF output power and minimizing degrading the S/N quality of the transmitted DVB-T signal is to run the drive power up until the shoulder break-point reaches -30 dB. At this point, I achieve a Crest Factor of about 8 to 10 dB. This means the average DTV power is -8 to -10 dB below the max. saturated power rating of the amplifier. This crest factor is required to avoiding clipping the peaks in the DTV signal and thus destroying it's S/N. Most DATV hams are thus content to use their transmitters, as is, radiating signals that look like Fig. 10. We typically do not have, nor can afford the cost of an exotic digital pre-distortion equalizer. For DATV repeater service however, the addition of a sharp cut-off, steep skirted, 6 MHz band-pass channel filter is absolutely required.

For additional reading on testing DTV transmitters, I recommend checking out the premier, German supplier of broadcast TV transmitters, Rohde & Schwarz's web site.

www.rohde-schwarz.com They have a large collection of relevant application notes and newsletters there.

REFERENCES:

1. "*Digital Video and Audio Broadcasting Technology*", by Rhode & Schwarz engineer, Walter Fisher. Published by Springer-Verlag, Berlin, Germany, 2010. See chapter 21, *"Measuring DVB-T Signals"*, pp. 421-450

2. "*Digital TV Rigs and Recipes -- Part 4, DVB-T*", S. Grunwakl, Rohde & Schwarz, Broadcasting Division, Application Note DigitalTV4, version 3.0, 13 Aug. 2002, 66 pages --- available as .pdf files to be downloaded from:
https://www.rohde-schwarz.com/us/applications/digital-tv-rigs-and-recipes-application-note_56280-15676.html