USB Power Supply RF analysis, Updated Testing

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Introduction

Five 12V USB power supplies are tested with a Signal Hound USB-SA44B Spectrum Analyser (SA) scanning the VHF region from 100.0-200.0 MHz. Three are lighter-socket plug-in units and two are in-panel units. A Baofeng rigid VHF-UHF rubber-duck-ish antenna was used as the sensor. In all plots shown the black trace is the baseline background RF with the bench power supply source set to 13.6V output. To mitigate changes in the background environment the black baseline trace was reset between most of the tests. In all plots the traces were an average of 10 sweeps. A Galaxy Tab 3 tablet with approximately 35% battery charge was used as the test load for the USB supply output as a battery-charging load.

Figure 1. The Units Under Test (UUT), designated UUT1-UUT6 from left to right. Unit descriptions are in the document text

The test units (UUT) are shown in Figure 1 and designated, left to right, as UUT1-UUT6. UTT1-UUT4 were tested in 2017 with similar results to the present testing. Two of the test units, UUT1-2, were purchased from Amazon:

https://www.amazon.com/gp/product/B00SWGWILI/ref=oh_aui_detailpage_o01_s01?ie=UTF8&psc=1

Figure 2. First type of power supply under test, with two separate units tested.

The second type of unit tested (UUT3) was a generic give-away spiff with Wells Fargo branding. The age and source of this unit are not known. In this testing UUT4 proved to be inoperational and provided no results. The 2017 test results for UUT4 are shown in the Analysis section. UUT5 is a BlueSea Systems marine USB charger socket popular with Experimental category aircraft builders. This device is indicated in the manufacturer's literature as having connected device recognition capability for smart-charging features.

https://www.bluesea.com/products/1039/12_24V_Dual_USB_4.8A_Chargers_-_Switch_Mount

UUT6 is an Appereo in-panel USB charger unit marked compliant to TSO-C71 and RTCA DO-160G. It is sold by Aircraft Spruce:

https://www.aircraftspruce.com/catalog/elpages/stratuspower11-14946.php

The Units Under Test are:

1. UUT1, a generic, low-cost, 12V lighter socket USB charger with a display that cycles between input system voltage, output current load, and ambient temperature.
2. UUT2, a second example of the same type as UUT1.
3. UUT3, a Wells Fargo branded inexpensive give-away spiff 12V lighter socket USB charger.
4. UUT4, a 12V lighter socket USB charger with a built-in CO detector. This unit was included in previous (2017) testing but proved inoperative for this test.
5. UUT5, a Blue Sea Systems model 1039 4.8A USB marine in-panel charging socket with 12/24V input.
6. UUT6, an Appereo 10-32V input 5A output (2.5A per port) in-panel USB charging socket, MPN 153510-000131, marked compliant to TSO-C71 and RTCA DO-160G.

Test Procedure

The baseline background trace, the black trace shown in the images, was generated with the test fixture bench power supply set to 13.6V output, the Galaxy Tab 3 on, and no UUT connected or powered. This provides an RF background energy reference to compare to measurements made with the UUTs powered with and without loads. Since the background RF energy is not static, the background trace was regenerated between most tests. The background (black) trace as well as the UUT emission trace (blue) are all averages of ten sweeps in the Spectrum Analyzer (SA).

UUT1 was connected first with no load, and then to the Galaxy Tab3 as a battery charging load with an indicated load of 1.17 Amps. Figure 3 shows the increase in the radiated power levels due to UUT1 in both the unloaded (top) and loaded (bottom) conditions, relative to the background power levels sensed at the time (black trace). Figure 4 shows the results for UUT2, a similar device, in the same conditions. For UUT2 the indicated load current charging the Galaxy Tab3 was 1.11 Amps. It can be seen for both UUT1 and UUT2 that the radiated energy from these devices is significant, roughly 10-15dB higher than the background energy in the 105-125MHz region occupied by aviation VHF voice traffic when loaded, and even in the unloaded case for UUT2. Additionally, even though the devices are the same products, their radiation characteristics differ significantly. This was seen in earlier testing as well, that like devices may not exhibit the same radiation characteristics. However, the author notes that his aircraft flies regularly with two of these devices continually providing power to multiple tablets/cellphones as well as a Stratux unit with no noticeable effects on communication or navigation radios or other equipment.

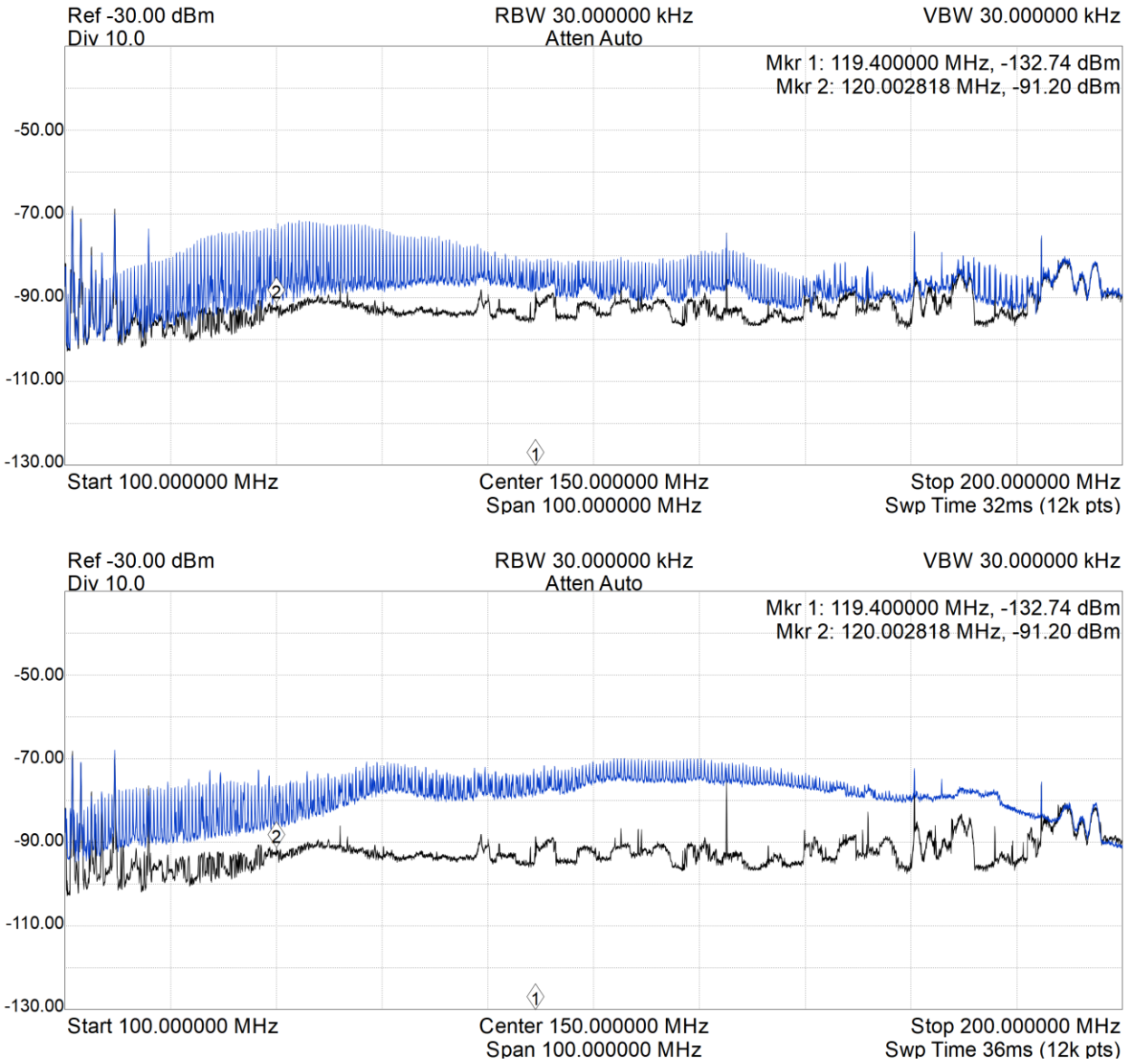

Figure 3. Unloaded (top) and loaded (bottom) plots of the radiated power spectrum including the radiated power for UUT1 (blue trace) and the background power levels (black trace). For this unit the emissions in the loaded condition were significantly higher than with no load.

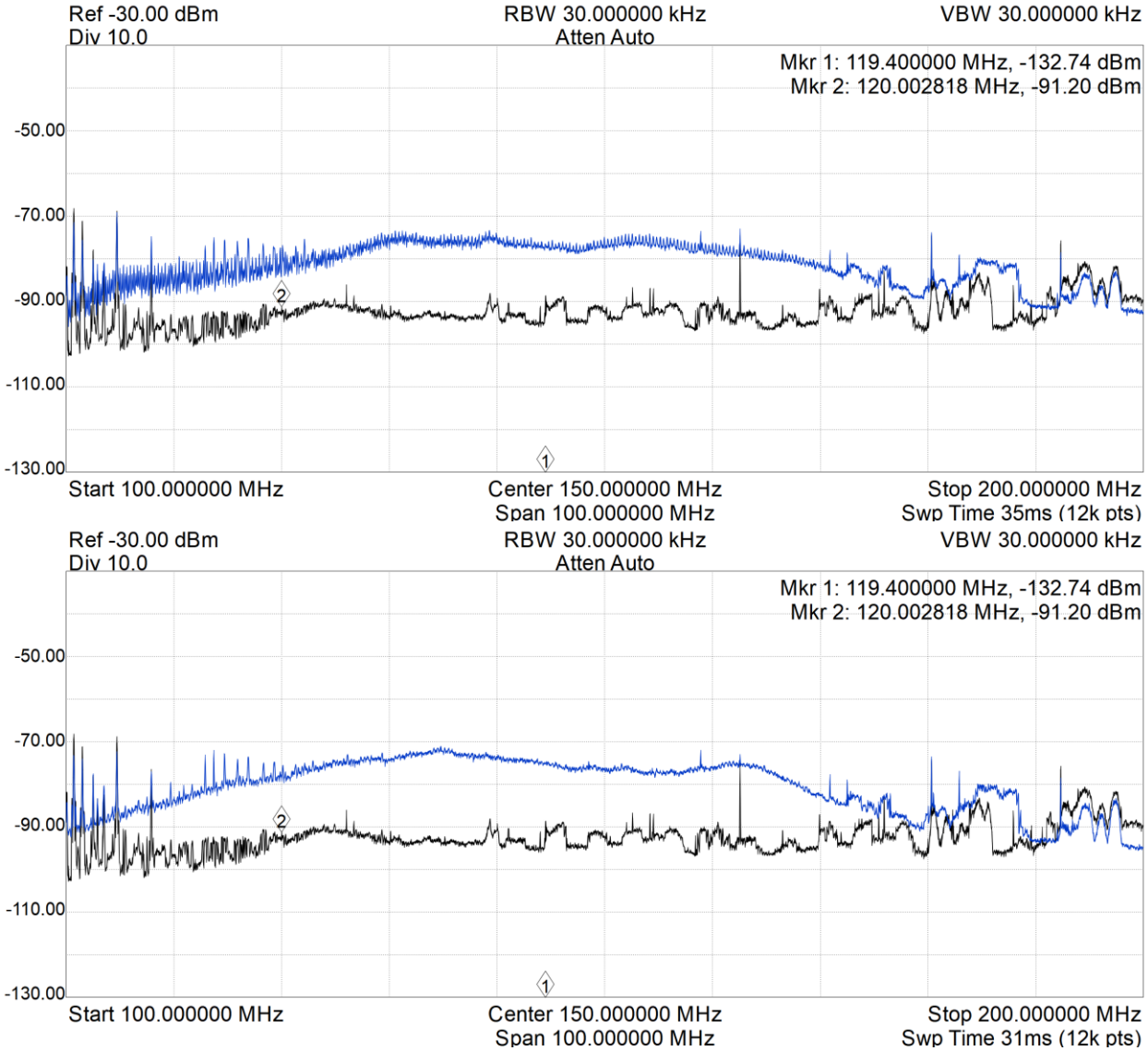

Figure 4. Unloaded (top) and loaded (bottom) plots of the radiated power spectrum including the radiated power for UUT2 (blue trace) and the background power levels (black trace). The loaded emissions are higher than the unloaded condition, but for this unit the emissions in the unloaded condition were still significantly higher than the background energy.

The output of UUT3 in similar conditions are shown in Fig. 5 and shows very little increase in radiated energy compared to the background trace, even in the loaded condition. In the unloaded condition the detected energy with UUT3 powered is essentially indistinguishable from the measured background energy. This is consistent with its performance during previous testing, where it was the quietest of all units tested.

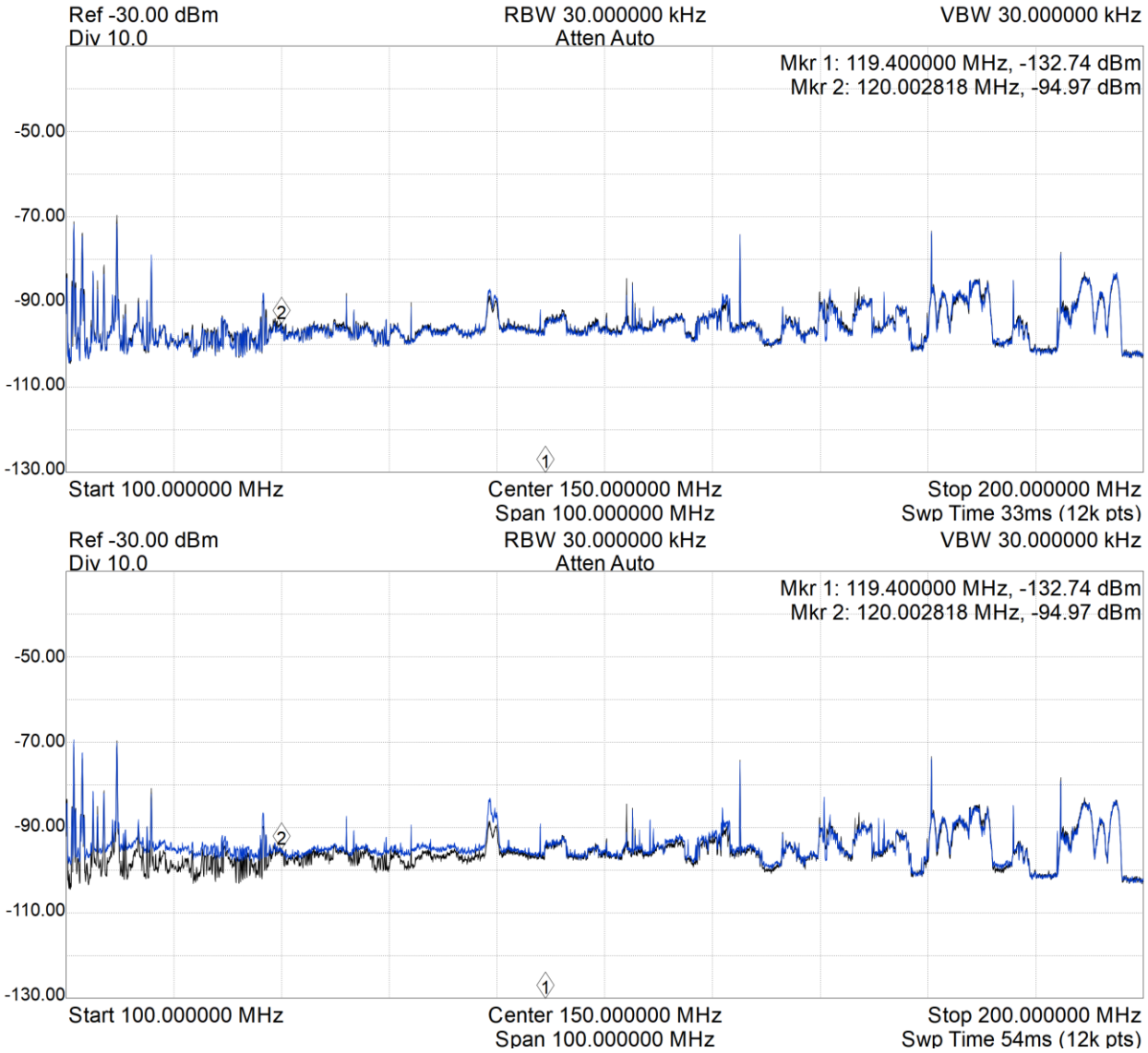

Figure 5. Unloaded (top) and loaded (bottom) plots of the radiated power spectrum including the radiated power for UUT3 (blue trace) and the background power levels (black trace). Even though this unit is an inexpensive, branded give-away item, it exhibits very low output emissions, especially compared to UUT1 and UUT2.

Test results for UUT5 are shown in Figure 6. This unit appears to be the only unit tested indicated as having device recognition features, i.e., it detects the connected device and adjusts its output for increased charging performance and reduced charge time. It also has reverse polarity detection, thermal overload and short circuit protection, and a conformal-coated circuit board for marine use. These features indicate that additional engineering and manufacturing efforts are applied in order to increase the robustness of the device compared to the UUT1-3 which are primarily low-cost units. Additionally, while the product literature for the device does not mention rf shielding specifically, it does say it includes "Internal filtering for reduced electronic interference". This unit does exhibit very low emissions levels in both unloaded and loaded conditions.

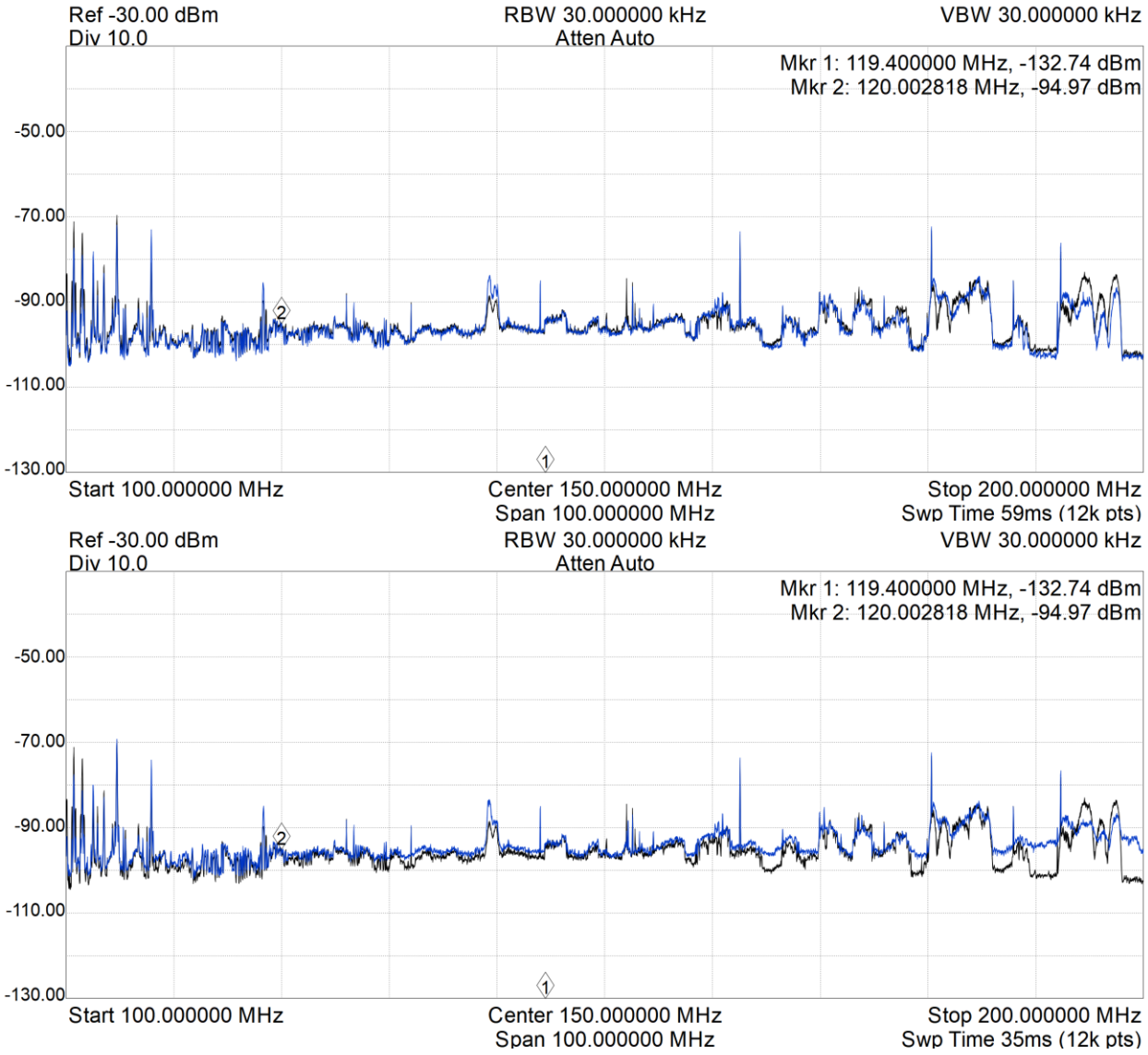

Figure 6. Unloaded (top) and loaded (bottom) plots of the radiated power spectrum including the radiated power for UUT5 (blue trace) and the background power levels (black trace). This unit shows very little increase in emitted radiation compared to the reference background levels.

The only device tested that was marked with TSO or RTCA compliance is UUT6, which shows both TSO-C71 and RTCA DO-160G compliance. The significance (or not) of these specifications will be discussed later in this document. This unit is also by far the most expensive unit tested, priced at about 8x the cost of UUT5 and about 30x that of UUT1-2. Although UUT3 was a promotional give-away, similar devices can be obtained for less than the cost of UTT1-2. Performance of UUT6 was marginally the best of all units tested and showed little discernible radiation in both the loaded and unloaded conditions.

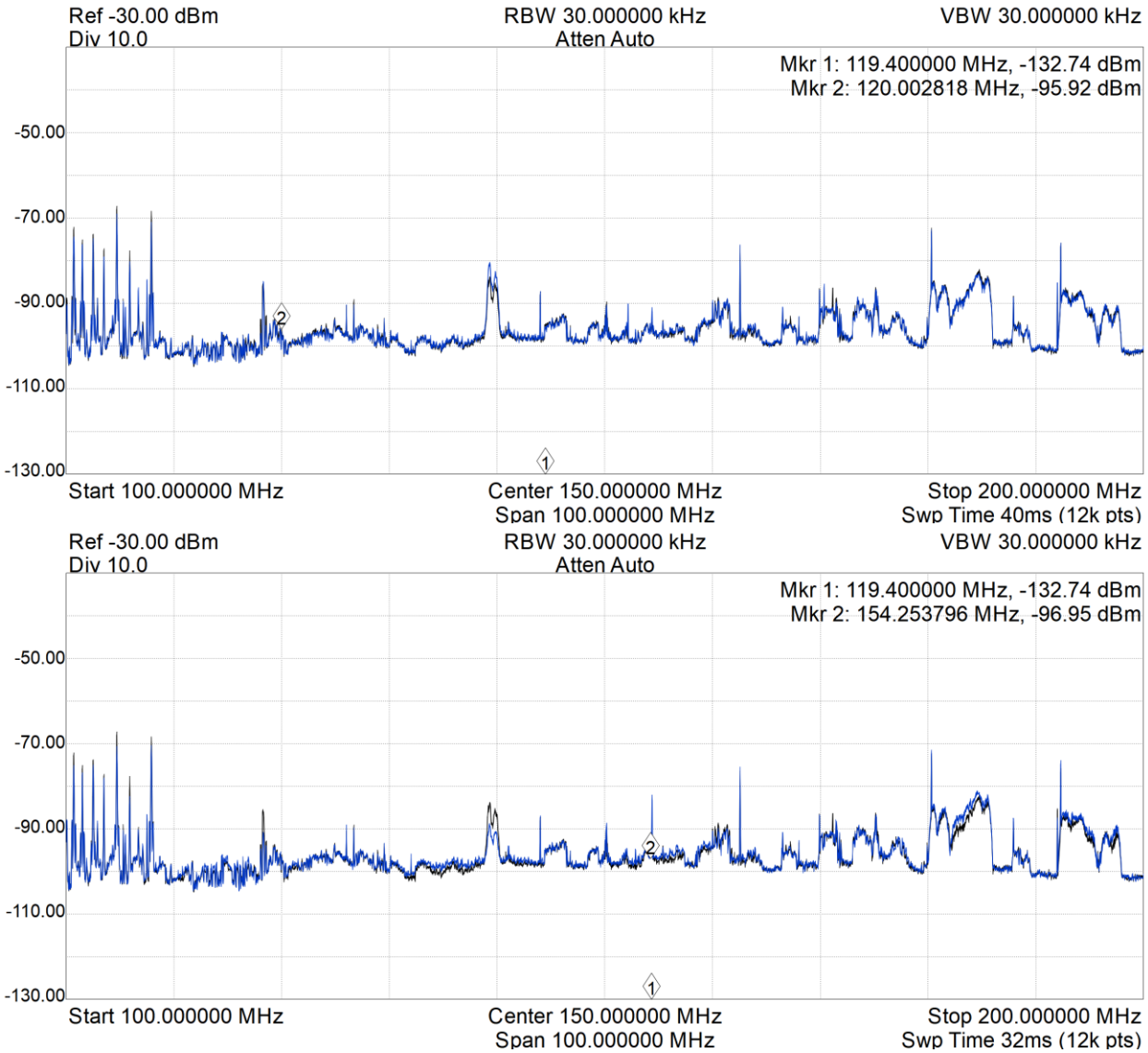

Figure 7. Unloaded (top) and loaded (bottom) plots of the radiated power spectrum including the radiated power for UUT6 (blue trace) and the background power levels (black trace). Like UUT4 and UUT5, this unit exhibits very little radiated energy in either loaded or unloaded condition.

Analysis

In the results presented here as well as in the previous tests, all of the units tested exhibited very low emissions levels in both loaded and unloaded conditions with the exception of the chargers of the type represented by UUT1 and UUT2 in this study. In both the previous study and this one, all chargers exhibited low radiation except for the style of UUT1-2, which were consistently noisier. Figure 8 shows the results from the unit labeled UUT4 in this study when it was operational in the previous study, where it exhibited low emission levels like UUT3-6 tested here. The level of the emissions from UUT4 in Fig. 8 are comparable to typical changes in the background reference over time and are not considered significant.

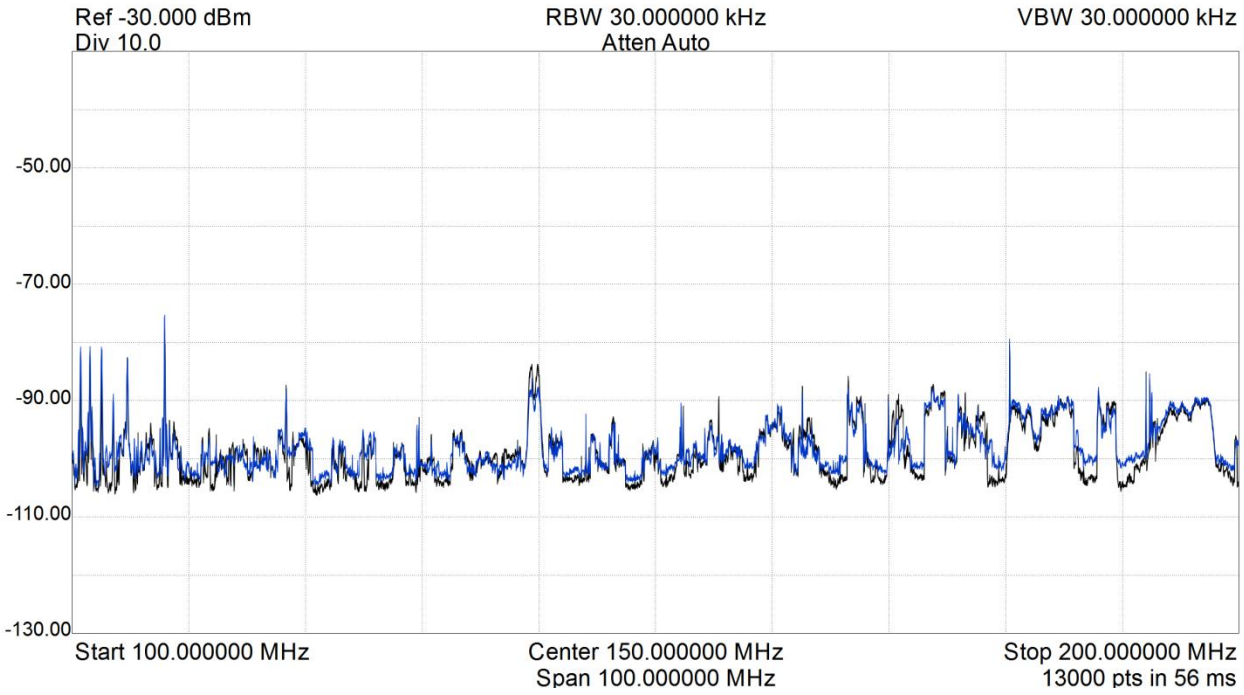

Figure 8. UUT4 output from a previous test with a 0.71A load. While emission levels are slightly further above the background reference level than some of the examples here, emissions are still quite low compared to UUT1-2 devices.

The existence of chargers that generate higher noise levels, like those seen with UUT1 and UUT2, is reason for caution when selecting devices for use or when troubleshooting interference with VHF communication or navigation equipment. Significant interference from plug-in USB chargers has been observed in the field where disconnecting the interfering plug-in USB charger restored the use of VHF communication equipment. If plug-in USB chargers are being used and interference is experienced, it is prudent to disconnect the charger to see whether it is the source of interference. Given the low cost of

plug-in chargers it is reasonably easy and inexpensive to replace a unit or keep spares if one does prove to be problematic. In this study, and the previous, only one type of plug-in USB charger displayed significant radiation at levels that could be potentially problematic, and all others produced emission levels that are very quiet with regards to rf energy and would not be expected to produce problems. Emission levels of all of the devices except UUT1-2 were consistent across the tests regardless of the purchase price or certification level of the units. This supports the notion that it is possible to use inexpensive plug-in chargers without degrading the performance of voice or navigation radios as long as some caution is used.

It should also be noted that only single examples of the types of chargers represented by UUT3-UUT6 were tested, so conclusions about uniformity of performance across all units of a type cannot be made. Assuming the tested units are representative of their type, rf emission levels would only be expected to be problematic across the UUT1-2 type tested (and all units of that type were similarly noisy), so selection of USB chargers based on rf emission levels seems to be generally safe with some exceptions.

In general it should also be noted that even the higher amount of emissions exhibited by UUT1-2 may not be sufficient to cause interference in all or even most installations. The author has used similar devices regularly for at least two years and over 200 flight hours with no noticeable degradation in performance of other equipment. The very small amounts of emissions exhibited by UUT3-6 are insignificant and comparable to the normal deviation of the background energy levels over time. Any of the UUT3-6 devices could be considered essentially radio-quiet for use in or near the radio equipment in a general aviation aircraft. The author has observed substantially higher emission levels from expensive, certified, in-panel equipment intended for use in certified aircraft.

Some Notes About Certifications and Specifications

Some users rely on marked certifications or specifications as a means to screen devices for lower radiation emissions or likelihood of radio interference. The two relevant specifications which are typically marked on devices in this context are TSO-C71 and RTCA DO-160G. We will address each of these below.

TSO-C71 is an FAA Technical Standard Order (TSO), which is a standard specification covering DC-DC converters. This is relevant to USB chargers, which convert from the aircraft 14V or 28V DC system voltage to the USB standard 5V output. TSO-C71 was released in 1961 and at the time covered DC-DC converters used in large aircraft, which at the time were implemented with mechanical vibrating relays, similar to old, pre-transistor voltage regulators. The specification covers things like output voltage regulation, voltage ripple, short-circuit protection, temperature sensitivity, etc. The section covering "Emission of Radio Frequency Energy" provides a conducted, not radiated, specification that "within the range of 90 kc to 1500 Mc shall not exceed 200 microvolts between any cable terminal to ground." There is no radiated energy specification, and a Note in the same section begins with, "It is recognized that the radio frequency emissions having a level considerably less than the maximum permitted by the above standard are capable of interfering with the operation of other electronic equipment in an aircraft installation," and goes on to say that cost considerations may exclude the measures necessary to

mitigate interference energy. Without going into any further detail, the point is made that TSO-C71 holds essentially no relevance to whether a product marked compliant to it will cause interference to any aircraft electrical system or not due to radiated, or even conducted, emissions. It is simply not a useful indicator of rf emission levels, requires no rf emissions testing for compliance, and is barely relevant to modern DC-DC converter industry standards which are no longer implemented with the technology that was the context of the document in 1961.

RTCA DO-160G is a private, industry, non-government, standard organization specification from the Radio Technical Commission for Aeronautics (RTCA). It covers a wide array of environmental specifications for airborne equipment including shock, vibration, temperature, humidity, fluid susceptibility, flammability, icing, etc. Multiple levels are defined for many of the tested characteristics so not all equipment has to meet the most stringent requirements and varying degrees of compliance may still carry the DO-160G compliant marking. It is therefore possible that a user shopping for a device with minimal rf emissions may select a unit marked compliant to DO-160G but which has, for example, only been tested for temperature and vibration susceptibility to the requirements of those sections in that document. The presence of the DO-160G marking only means that the unit has been demonstrated to meet at least one of the wide variety of tests included in that specification, and which tests or the level of compliance is not indicated in the product marking. The documentation of a product marked compliant to DO-160G should include a statement of what was tested and the compliance level met for the qualifications, and this is often included in an Appendix to the product installation or technical documentation. In the case of UUT6, which is marked as DO-160G compliant, the installation guide shows the DO-160G conditions tested and shows what categories were achieved in Appendix A of that document. It indicates that, among other tests, Emissions of Radio Frequency Energy were tested per DO-160G section 21.0 to the Category B level. Within that section Category B is the least stringent category of testing and the RTCA indicates “This category is intended primarily for equipment where interference should be controlled to tolerable levels.” There are five other test categories in section 21.0, two of which are specifically for “equipment and associated wiring” located near VHF or GPS antennas, but those levels were not met according to the product documentation.

The relevant industry standard for USB chargers is the USB specification itself, which assures that the charger will properly charge a USB-compliant device without exceeding limits that could be expected to damage the client device. The UUT5 product documentation indicates that it includes device recognition capability, which is part of the USB standard and allows improved, faster charging of compliant client devices. In addition to the USB standard specifications for these USB chargers, all electronic devices must meet FCC Part 15 radiation limitations for unintentional radiators, which are specifically intended to restrict interference to radio receivers and are fairly stringent. If the FCC Part 15 requirements are met, it is unlikely that properly installed equipment would experience interference. It has been observed, however, that not all equipment, TSO or RTCA certified or otherwise, meets the FCC requirements.

Conclusion

While there is variance in radiated emission outputs across the units tested in this test and the previous testing, all but one style of charger exhibited very low output emissions in the tested region from 100-200 MHz. The UUT1-2 devices exhibited notable radiated energy as measured with the Spectrum Analyzer, but the measured rf emissions of the remaining devices were essentially negligible. Since it is clearly possible for a user to employ a USB charger with radiated levels at or above those shown by UUT1-2, caution should be used and if interference with VHF voice or navigations systems is experienced, one mitigation strategy could be to disconnect any USB chargers currently in use. Test results indicate that even the lowest-cost USB chargers may exhibit minimal rf radiation comparable to even the most expensive, TSO or RTCA certified, equipment. Likewise, certification to TSO-C71 or RTCA DO-160G standards does not assure low rf emissions. If interference from a USB charger is suspected, unplugging the charger from the aircraft electrical system during the interference event may reveal whether the unit is responsible for the interference.

Since rf emissions testing isn't readily available to most consumers to characterize a particular device, some trial and error may be required in selecting a replacement if a particular USB charger exhibits radio interference. Given the wide availability of low-cost solutions and the apparent low emissions of many, if not most, candidate lighter socket plug-in USB charging equipment, it is expected that suitable units could be easily obtained.