Title: Chamber Day '23	***Author:*** O'Neil, Beaudet, Leyzorek	***GBT Memo 310*** ***RFI Memo 124***

Results from Green Bank Observatory's Chamber Day 28 September, 2023

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Change Record

VERSION	DATE	REASON
1.0	03 Oct 2023	Initial Document
2.0	11 Oct 2023	Edits form co-authors, staff with tested equipment

CONTENTS

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1 BACKGROUND

On 28 September, 2023, Green Bank Observatory held a "Chamber Day," an opportunity for staff to test a variety of equipment in the anechoic chamber to determine the equipments' intentional and unintentional emissions. The equipment brought in for testing was a variety of specialty work equipment and everyday items common in society. Here we present the results of the everyday items only. Results of all tests were given to the equipment owners and are available upon request to the Interference Protection Group (IPG).

It is important to note that the tests taken on Chamber Day, and subsequent results given here, are not the result of exhaustive testing across all possible frequencies, nor was the time taken to delve deeply and look for all lines which may interfere with the operation of the site telescopes. Instead the observations were quick looks to understand better the emissions of this equipment at the frequencies of interest to the equipment owner. **As a result, the lack of emissions seen for any given piece of hardware in this report does not mean that piece of equipment will not cause harmful interference for any of the site telescopes.** Similarly, permission to use any equipment on site cannot come from the results in this memo, or the results from that day, but should follow proper procedures for full testing in the anechoic chamber.

2 PORTABLE PHONES

2.1 Overview

A number of portable telephones were tested. These included three generations of iPhones (7, 12, and 15) and one android phone. Not surprisingly, when intentionally transmitting, all phones were shown to be quite noisy in the WiFi bands. A number of significant conclusions were found with the phones:

1. **The majority of phones continue to transmit even when powered off**. The only means to ensure a phone is not intentionally transmitting is by turning off the phone's cellular, Bluetooth, WiFi, and location services. Note that "power off" for these tests is a full power down of the phone, and not merely turning off the screen.
2. For iPhones, **turning off Bluetooth using the home screen "swipe" feature is insufficient**. This action merely disconnects the phones from any Bluetooth device but does not stop the phone from transmitting a Bluetooth signal. The phone is only not transmitting Bluetooth if the phone shows a general prohibition (circle with a slash) signal, which is typically achieved through going into the phone settings and turning off transmission.
3. For some phones, the location services must be manually turned off or the phone will continue to transmit in the 2.4 GHz.

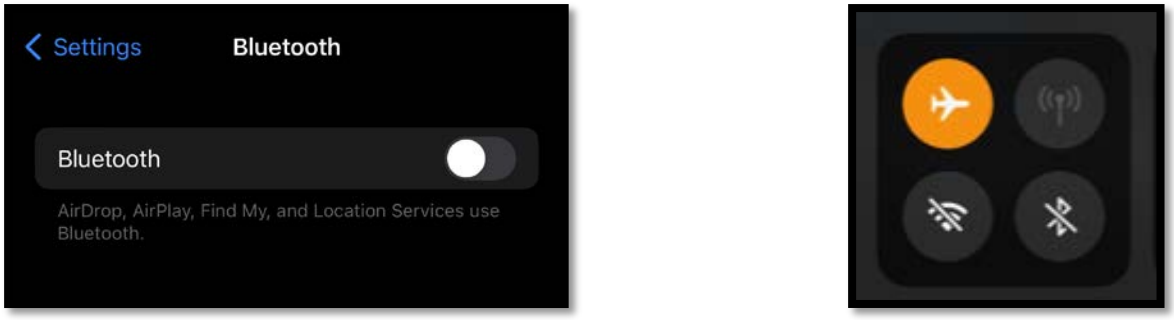

Figure 3. For the iPhones, the only method for turning off Bluetooth, rather than simply disconnecting it, is through the settings(left). This can then be seen in the 'swipe' method by the prohibition sign through the Bluetooth setting (right).

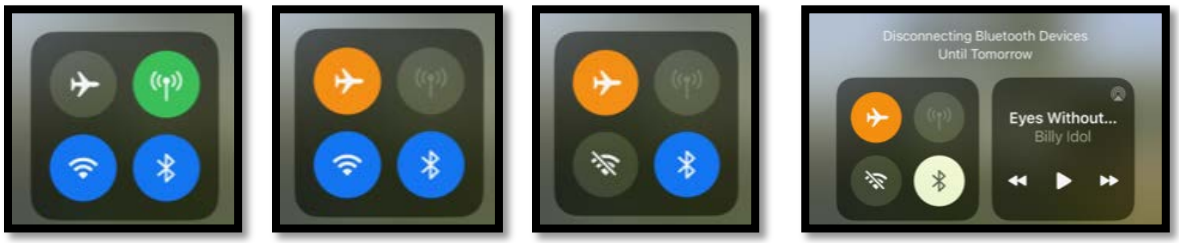

Figure 2. Results of turning off the various transmission features on an iPhone 12 using the 'swipe' feature. From left: all on; airplane mode on (loss of cell service only); WiFi turned off with swipe button; Bluetooth disconnected but not turned off (see Figure 3). Note that none of the buttons affects location services.

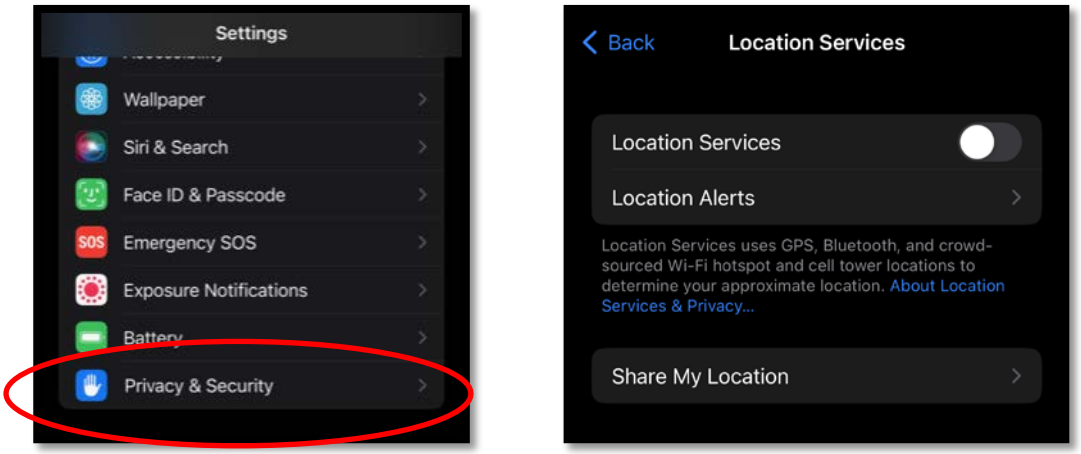

Figure 1. Turning off location services within the iPhone 12. All phones tested have similar methods for turning on and off location services. Note, too, that turning off location services in iPhones does not disrupt the 'Find My…" capabilities. That is responsive (passive) only.

2.2 iPhones

2.2.1 Overview

Three different generations of iPhones were tested – iPhone 8, iPhone 12, and iPhone 15 (which had only just been released at the time of the testing). Of these, not surprisingly, the sophistication of the system increased with each generation. When powered off, the iPhone 7 ceased transmission, at least in the tested 2.4 GHz WiFi band, while the other two did not. Additionally, as noted above, the use of the airplane mode for all three phones did not affect any of the tested bands (we did not look at signals in the cell phone range for these tests). Similarly, though, use of the "swipe" feature to turn off signals was not successful for blue tooth (Figure 1 - Figure 3). Results of all tests are in the next subsections.

2.2.2 IPhone 12

The most extensive testing was done on an iPhone 12. Results of the tests across the 1-18 GHz range and in the 2.4 GHz WiFi band are shown in Figure 4 and Figure 5.

There may have been additional intermittent signals that were not detected during this experiment, especially when measuring across the entirety of the 1-18GHz range. The combination of the broad band, brevity of signals from the devices, and limited instantaneous bandwidth of the detector lead to a low chance of actually catching a given transmission. Each measurement was taken over a period of several minutes to increase the chances of intercepting as many transmissions as possible, but it is still important to realize that the peaks shown represent only an unknown percentage of signals actually being emitted, especially over the broader bandwidths.

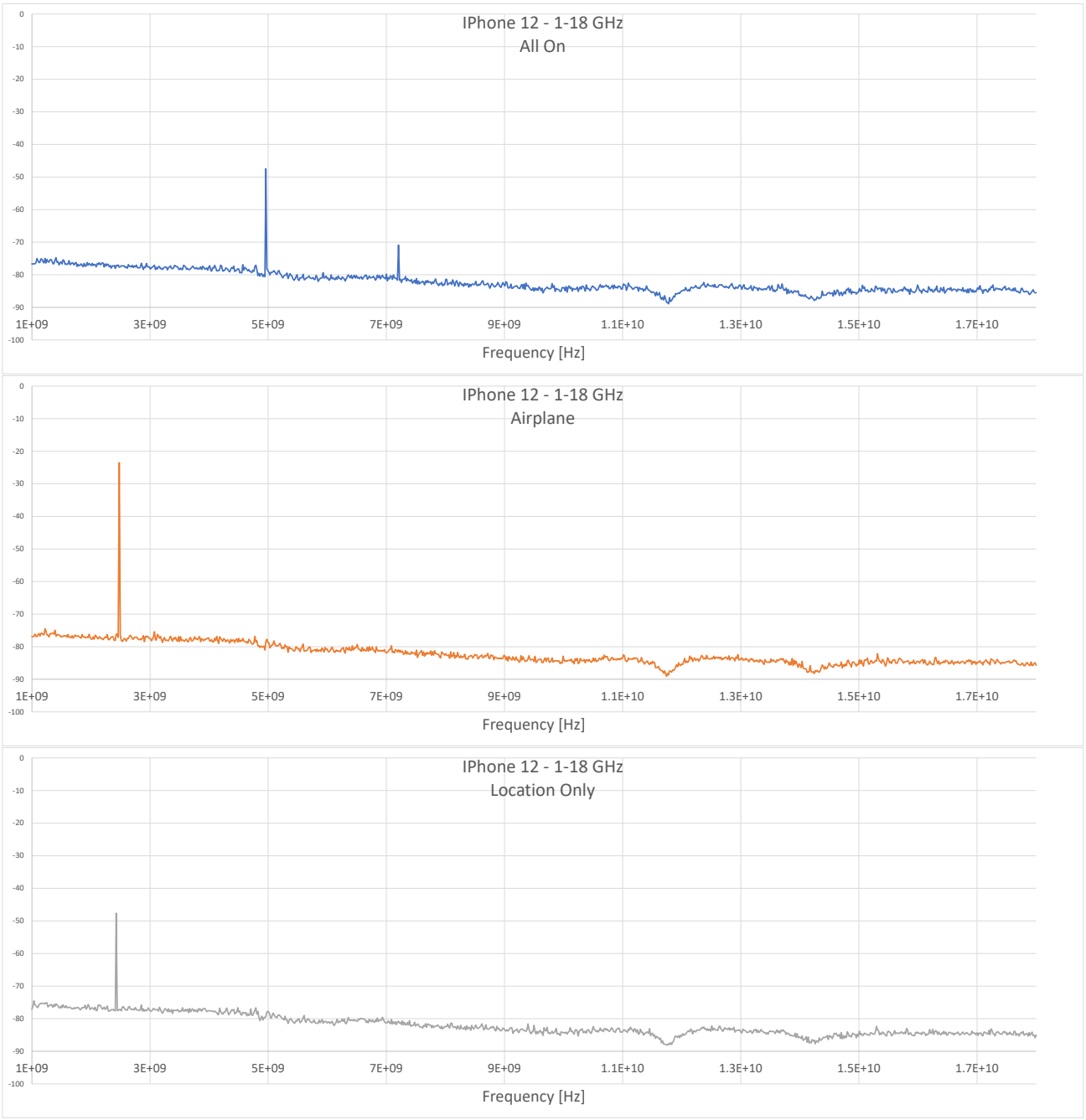

Figure 4. 1-18 GHz spectrum showing the iPhone 12 in three modes. From top to bottom: All intentional transmission services on; Airplane mode (cell service turned off, which also appears to have shut down the 5 GHz WiFi); All intentional services off except location services.

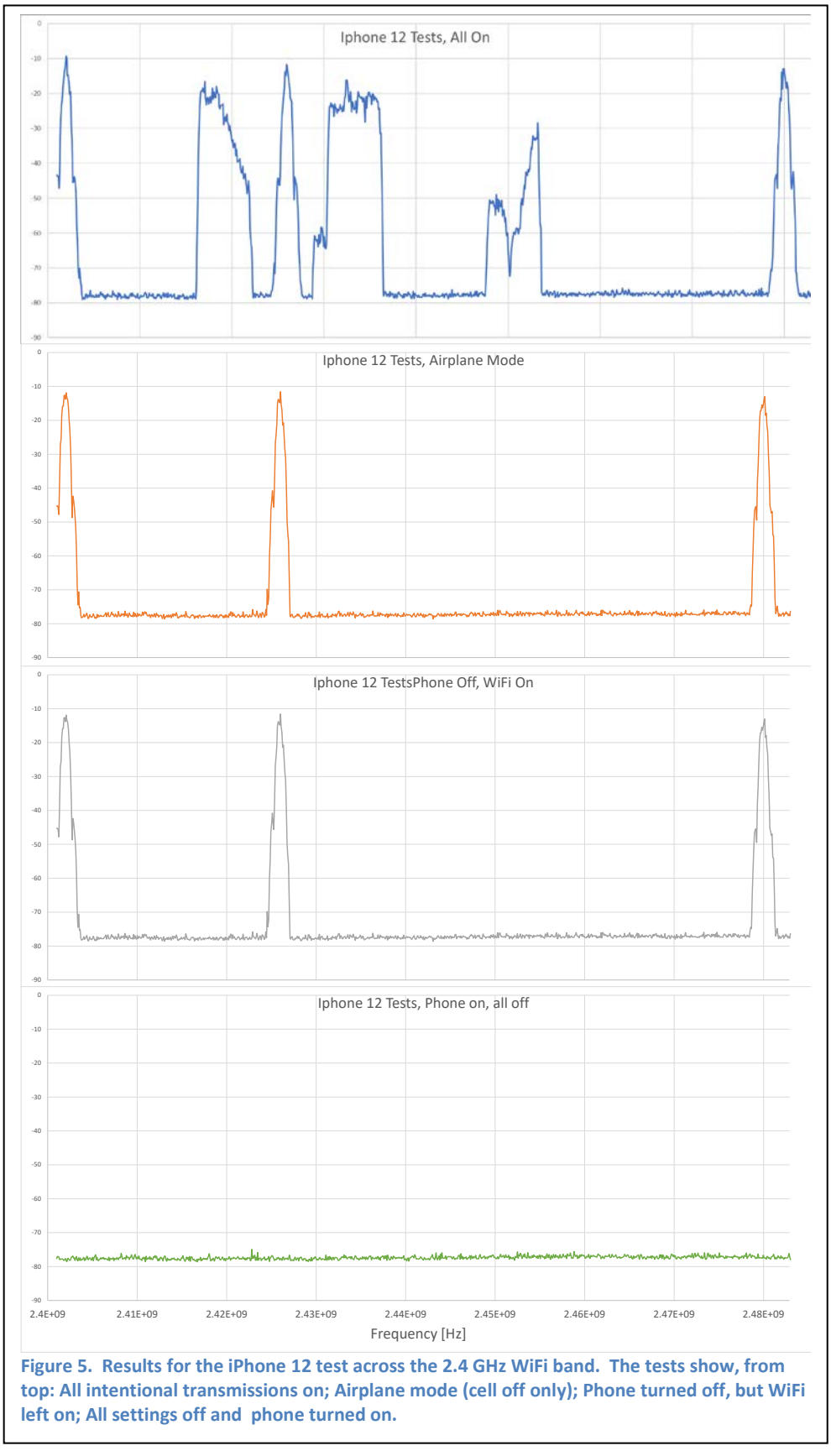

Figure 5. Results for the iPhone 12 test across the 2.4 GHz WiFi band. The tests show, from top: All intentional transmissions on; Airplane mode (cell off only); Phone turned off, but WiFi left on; All settings off and phone turned on.

2.2.3 IPhone 15

The primary test for the iPhone 15 was to determine if turning off the phone turned off the intentional transmissions in the 2.4 GHz range. The results can be seen in Figure 6which clearly show that simply turning off the phone as no effect on the transmissions. Instead, like the iPhone 12, the intentional transmissions must be turned off manually to quiet the phone.

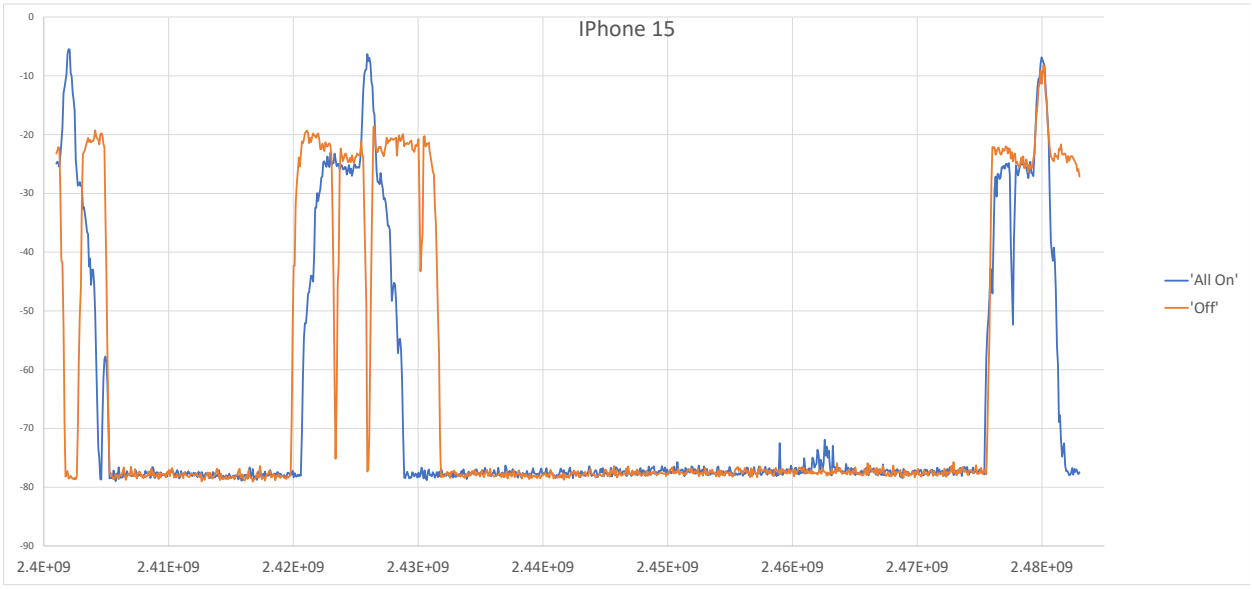

Figure 6. Results from the 2.4 GHz WiFi tests on the iPhone 15. Here is clear the turning off the phone (orange lines) had no effect on the intentional transmissions from the phone in this band.

2.2.4 iPhone7

The iPhone 7 was tested again only to see if turning the power on the phone off would affect the intentional transmissions in the 2.4 GHz range (the only WiFi range the phone is intended to use). Here the results clearly show that powering off the phone does indeed power down the 2.4 GHz intentional transmissions (Figure 7).

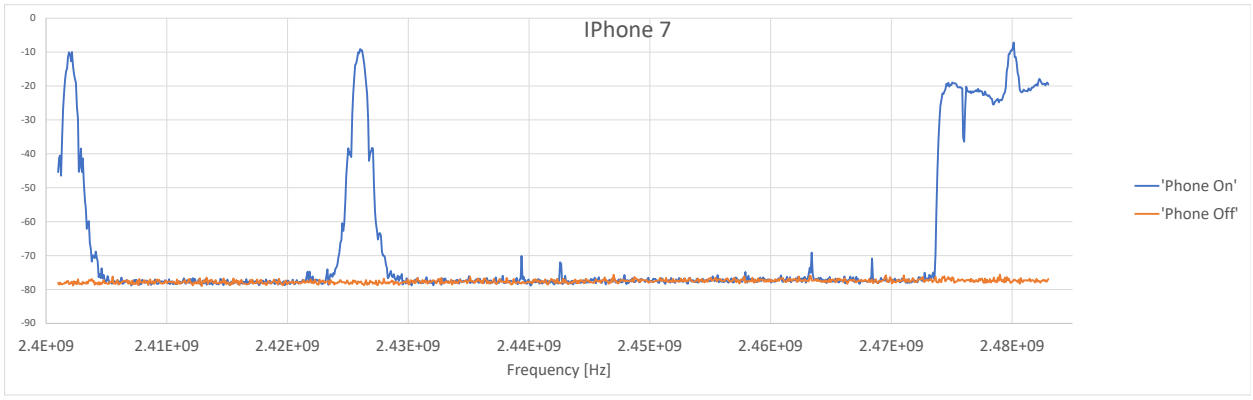

Figure 7. 2.4 GHz WiFi tests of the Phone 7. Here it is clear that turning off the phone ends all intentional transmissions in this range.

2.3 Samsung Galaxy 10

The only Android phone tested was a Samsung Galaxy 10. Here only three tests were undertaken – 1-18 GHz spectra when the phone and all intentional transmitters were on; 1-18 GHz spectrum when all intentional transmitters were turned off except for location services; and 2.4 GHz WiFi spectrum when intentional transmitters were turned on. The results can be seen in Figure 8.

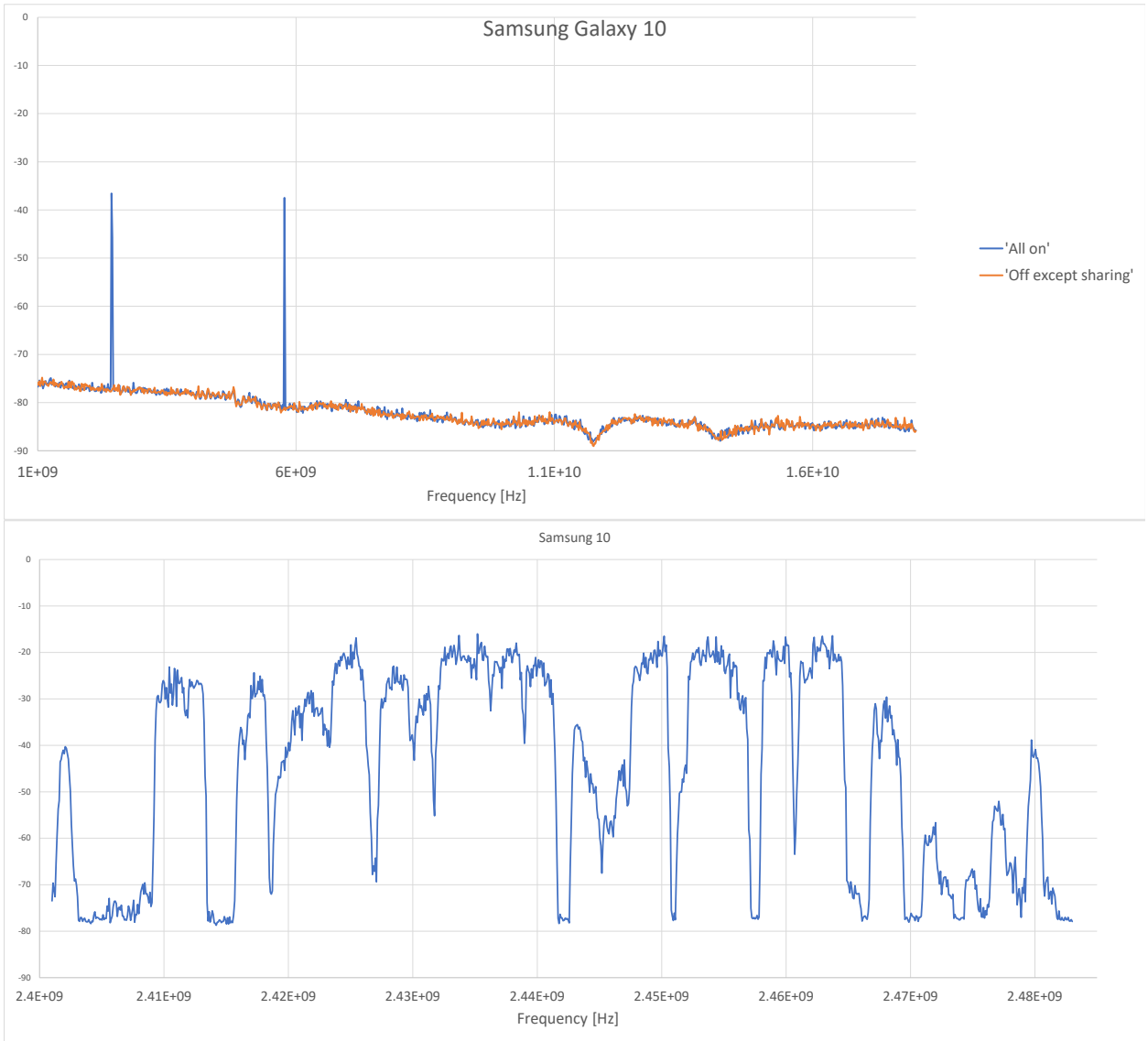

Figure 8. Test results from the Samsung Galaxy 10. At top shows the phone with all intentional transmitters on (blue) and with all but the location services turned off (orange). Bottom pot shows the 2.4 GHz WiFi with all intentional transmitters turned on.

3 WATCHES

3.1 Overview

Three types of watches were tested during Chamber Day – an Apple Watch (Series 5), a fitness watch (ditto), and a simple (not "smart") digital watch, for comparison purposes. Of these, the fitness watch appeared to transmit across the most frequencies, while no transmissions from the digital watch were seen for the tests undertaken (Figure 9).

Details from the Apple Watch test are given in the next subsection. As a note, though, testing was also done on a FitBit system in 2015. Details on that test can be found on the local Green Bank file system[1].

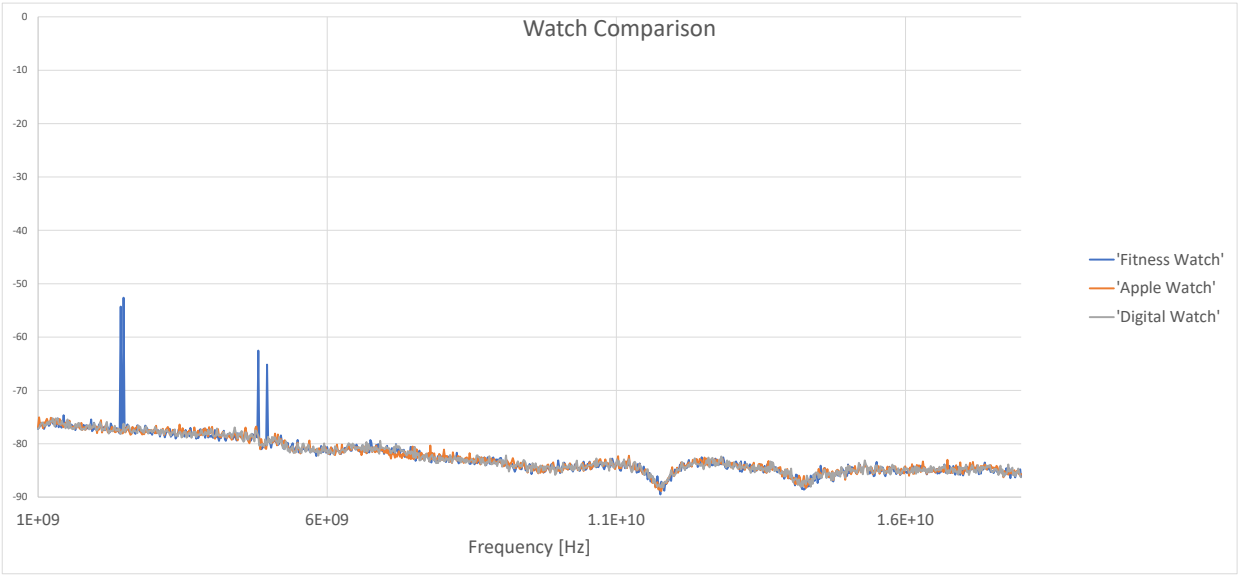

Figure 9. Comparison across the 1-18 GHz range of the three watches tested, with all intentional transmitters turned on.

3.2 Apple Watch

The Apple Watch (Series 5) was more thoroughly tested than the other two watches. Figure 9 and Figure 10 shows the results of these tests. Significantly, when the watch was completely powered off, the transmissions in the tested 2.4 GHz range appear to subside.

[1] \gbfiler\doc\IPG\AnechoicChamberTesting\RF Emissions Testing\Zones1-2\Zone2\FITBIT

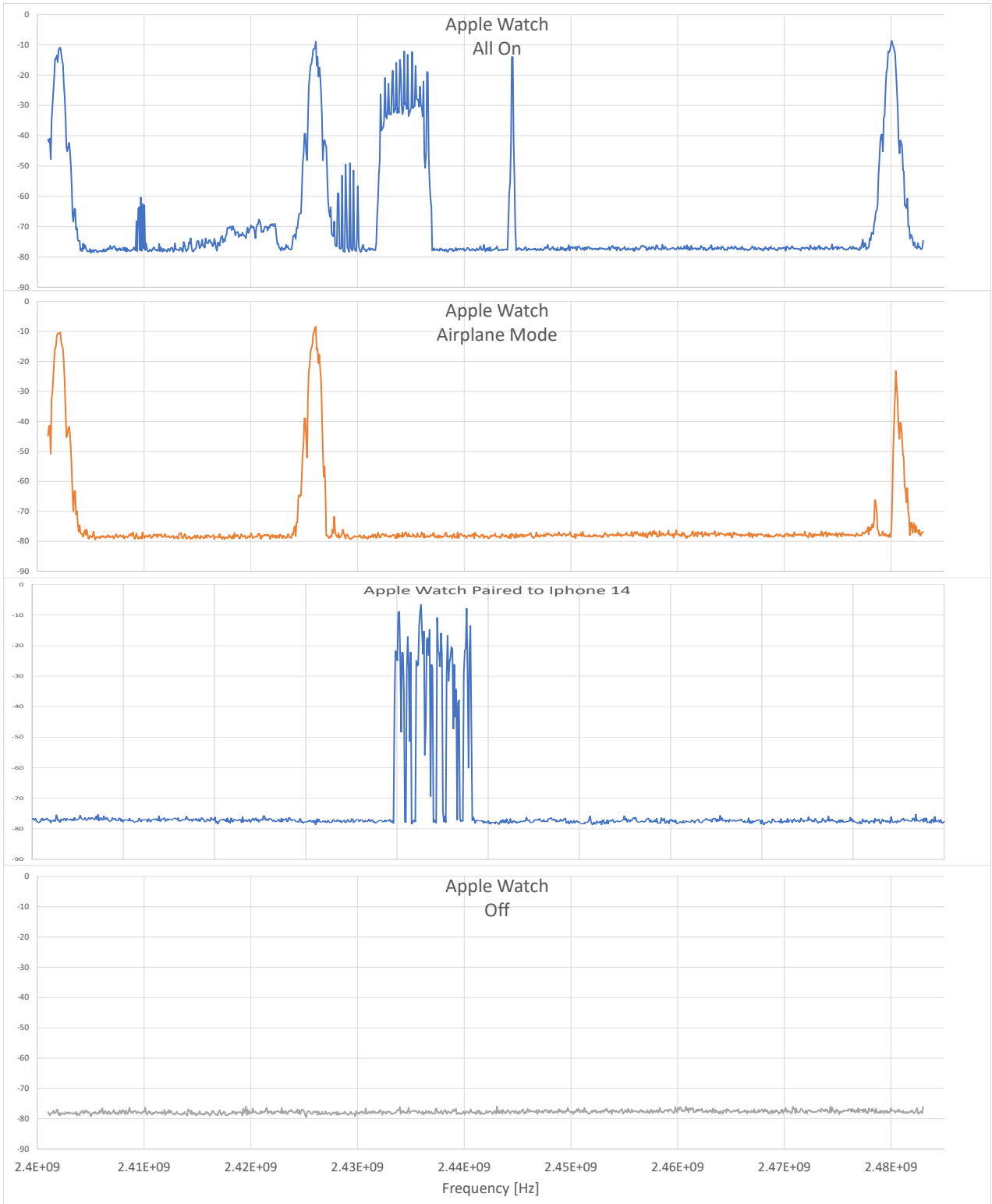

Figure 10. Apple watch tests across the 2.4 GHz WiFi spectrum. From the top: watch fully transmitting; watch in airplane mode; watch transmitting but paired to a phone; watch powered off.

4 CAMERAS

4.1 Overview

Five separate cameras were tested during Chamber Day. Four – Cannon EOS30E, Nikon D3, Nikon D3200, and Nikon Z6 – are SLR cameras and were tested across the 20 MHz – 1.0 GHz range to look at emission from the digital electronics. The fifth camera was the camera on the iPhone 15, which was tested in the 1-2 GHz regime to look for transmissions in that band due to photographs being taken.

The results from these tests are in the next two sections. What is clear is (1) the digital electronics associated with SLR cameras creates significant interference for radio astronomy signals; and (2) the act of taking a photograph, even without a flash, is extremely noisy[2].

Results from the tests are in the next two subsections.

4.2 Single-lens Reflex (SLR) Cameras

All four SLR cameras should extremely similar properties, and all showed clear emissions across the tested 20MHz – 1 GHz range. As a result, only some of the results are shown in Figure 11- Figure 13.

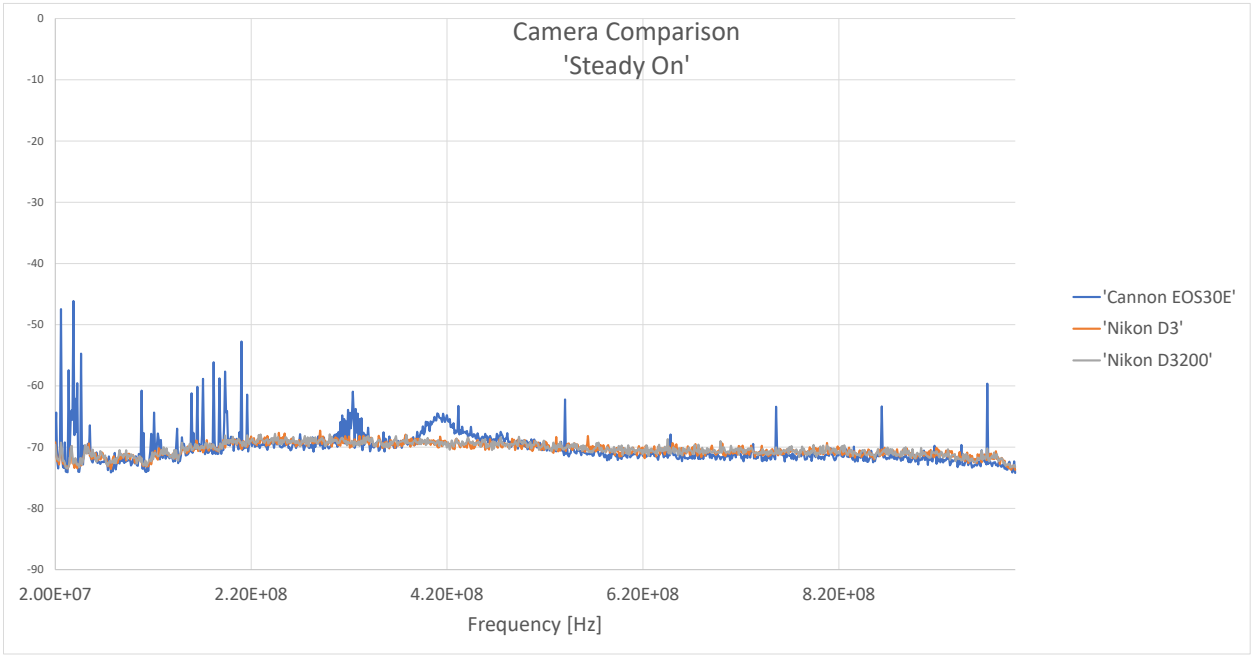

Figure 11. Spectra from three cameras (Cannon EOS30E, Nikon D3, and Nikon D3200) in the on state, without any photographs being taken.

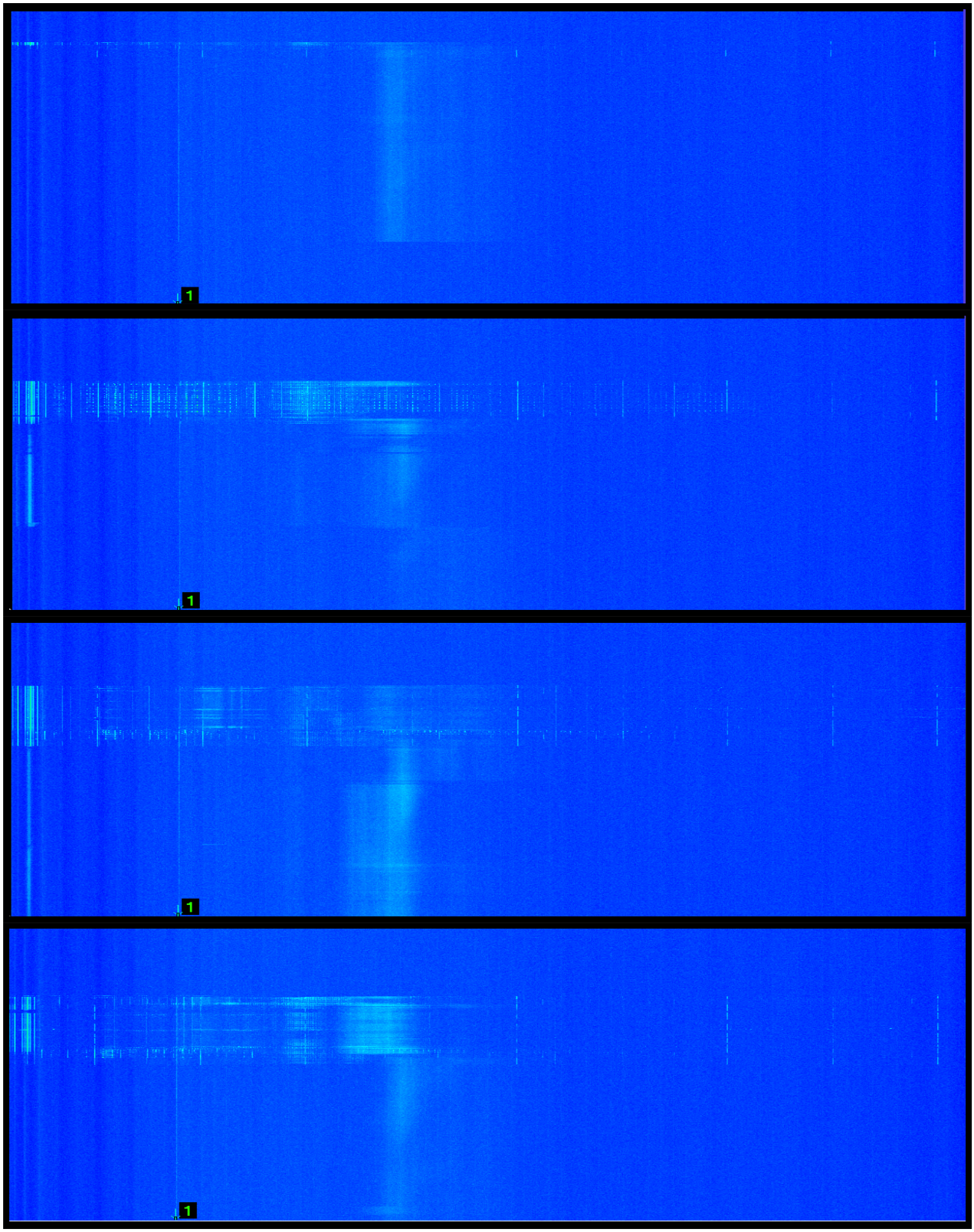

Figure 12. Waterfall plots showing the four tests taken with the Canon EOS30E camera. From top: Camera turned on; Camera on with viewer turned on; Camera on with viewer and photograph taken, but no flash; Camera on with viewer and photograph taken using a flash. Plots are from 20 MHz – 1 GHz (horizontal axis). The total time (vertical axis) varies from 1.5-5 s. For references, a marker is shown in all plots at 190.5 MHz

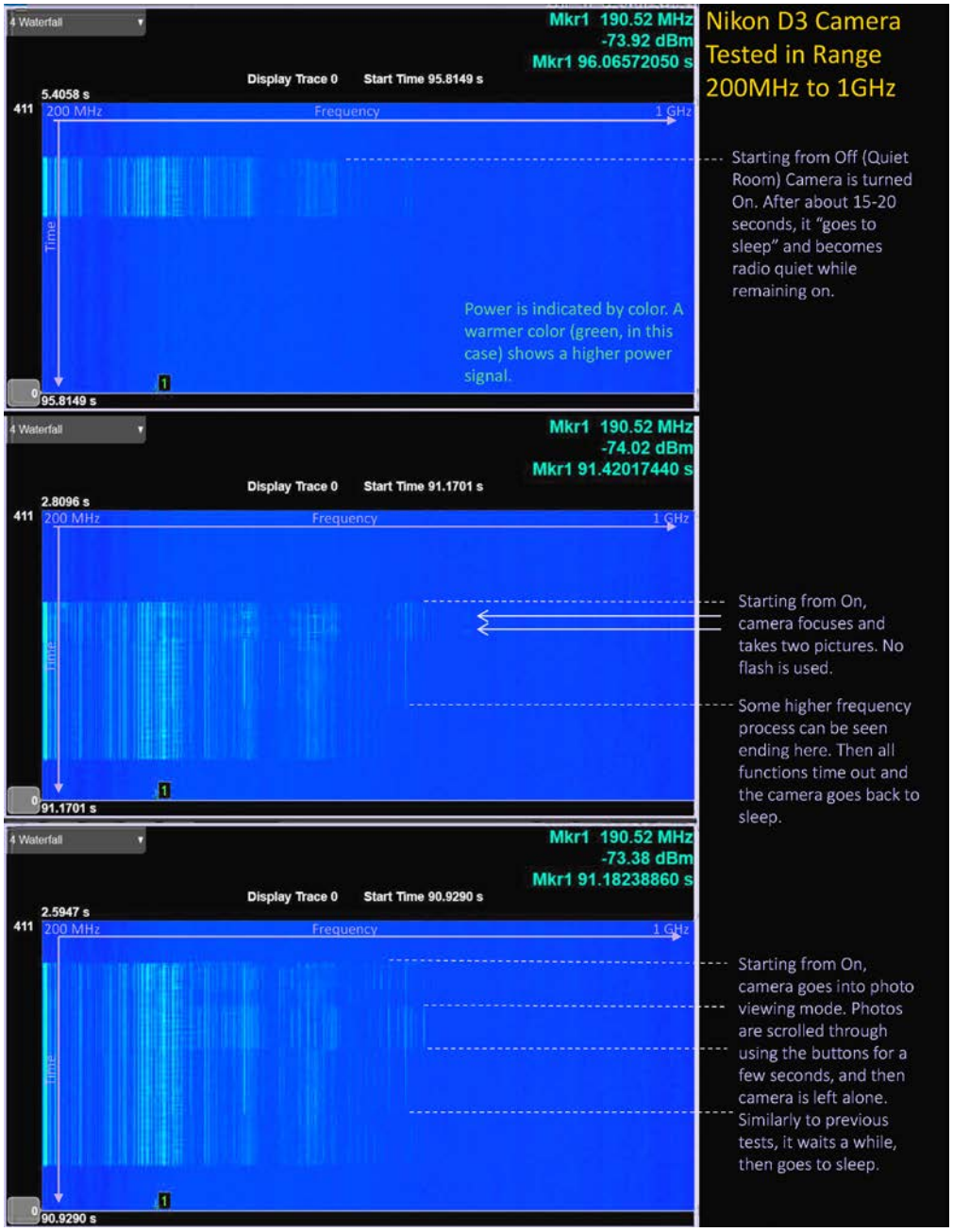

Figure 13. Waterfall plots showing the three tests taken with the Nikon D3 camera. From top: Camera turned on; Camera on with viewer turned on; Camera on with viewer and photograph taken, but no flash. Plots are from 20 MHz – 1 GHz (horizontal axis). The total time (vertical axis) varies from 1.5-5 s. For references, a marker is shown in all plots at 190.5 MHz. (Image and description courtesy of L. Leyzorek.)

4.3 iPhone 15

As can be seen readily in Figure 14, even the relatively quiet iPhone 15 shows clear unintentional transmissions when photographs are taken.

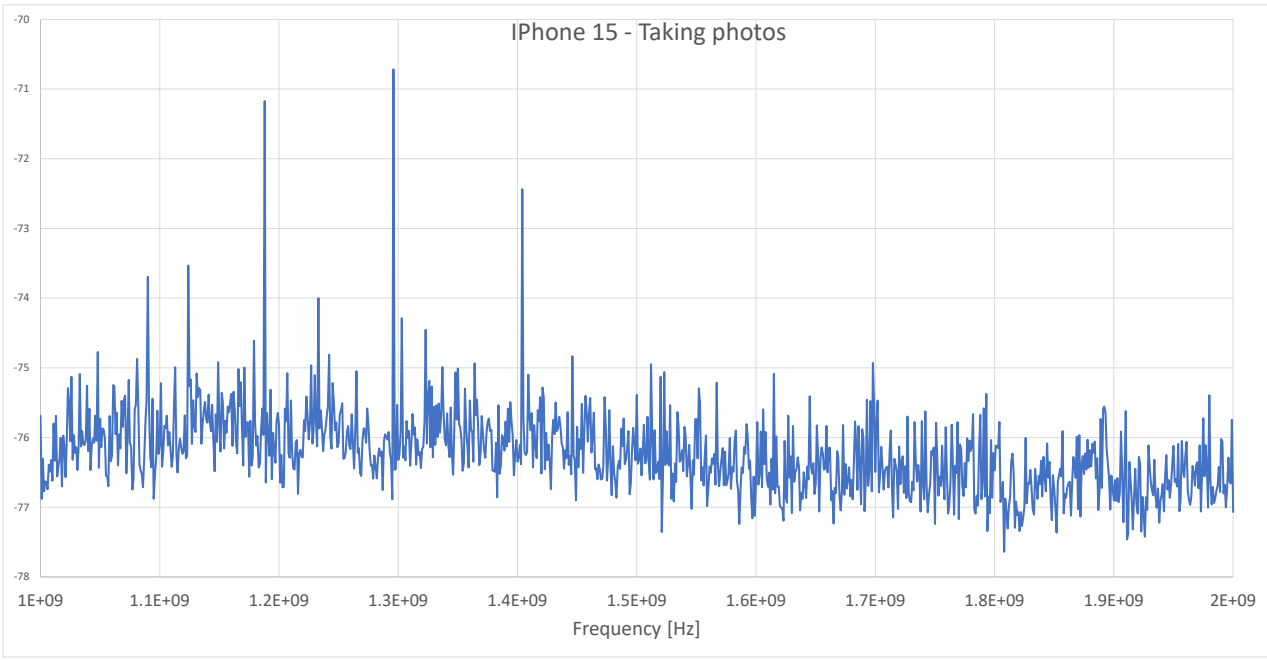

Figure 14. 1-2 GHz spectra showing the unintentional transmissions resulting from photographs being taken with an iPhone 15.

5 KEY FOB FOR CAR

A brief test was done across the 265-365 MHz range to determine the emission of a typical vehicle key fob. Here the test was done using the key fob for a 2013 Subaru Forester, but it is expected that most key fobs for standard ignition (rather than wireless) vehicles will be the same. The results were surprising only in the significant power given off by the key fob, as can be readily seen in Figure 15.

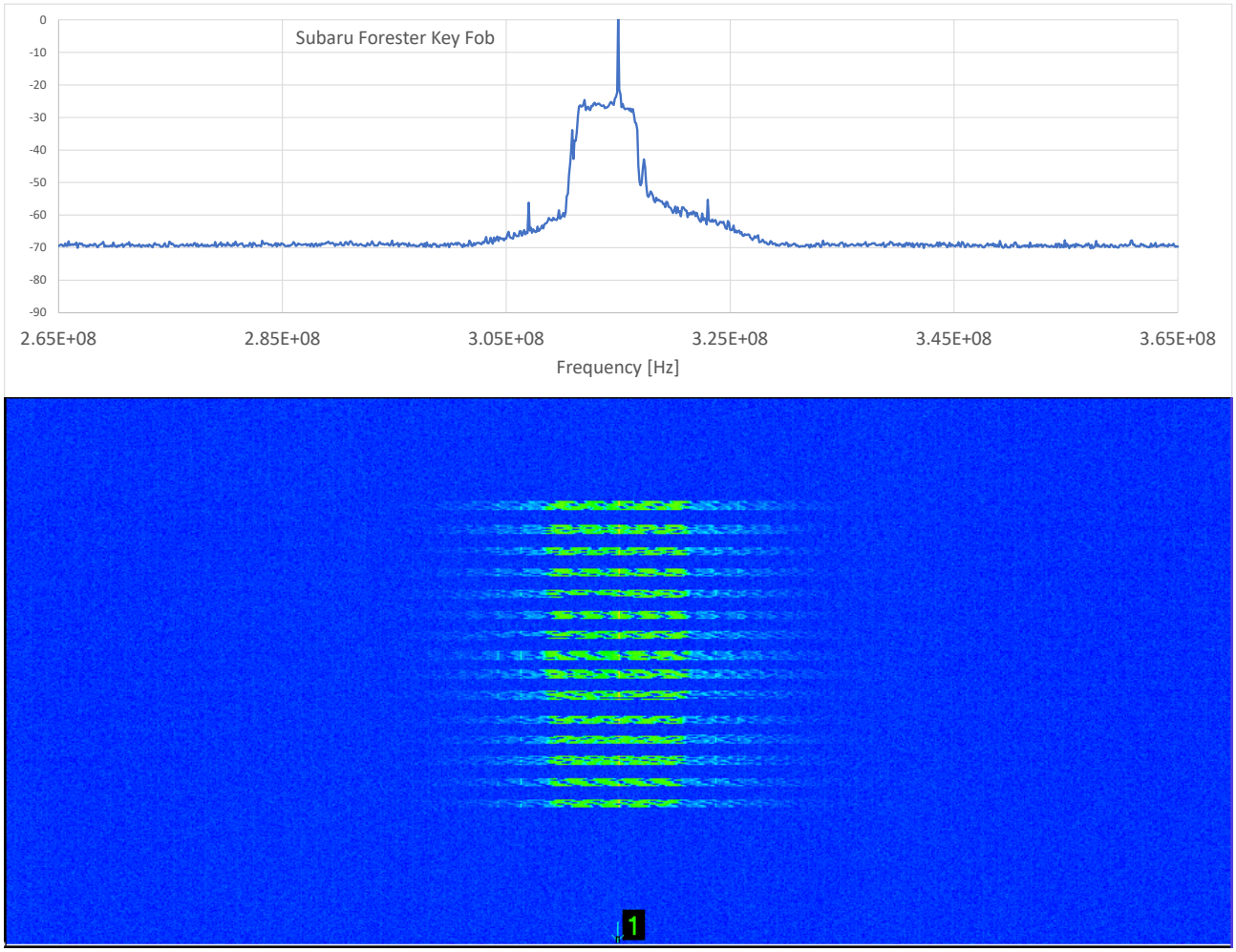

Figure 15. Test results across the 265-365 MHz range when pressing the buttons on a 2013 Subaru For ester's key fob. The top shows the spectral result and the bottom shows a waterfall plot with the three key fobs being pressed 5 times each (the bottom five are the unlock button; the middle five are the lock button, and the top five are the trunk button). The frequency range for both plots is the same, and the marker in the bottom waterfall plot is at 315 MHz.

6 WIRELESS CHARGER

A test was undertaken to look for emission from a wireless charging station. Here, though, it was difficult to separate the unintentional transmissions from the charging station with the unintentional transmissions from the power supply for the charging station. Regardless, it is clear the charging station produces some unintentional transmissions, but that the power supply, a small charging battery is significantly noisier (Figure 16).

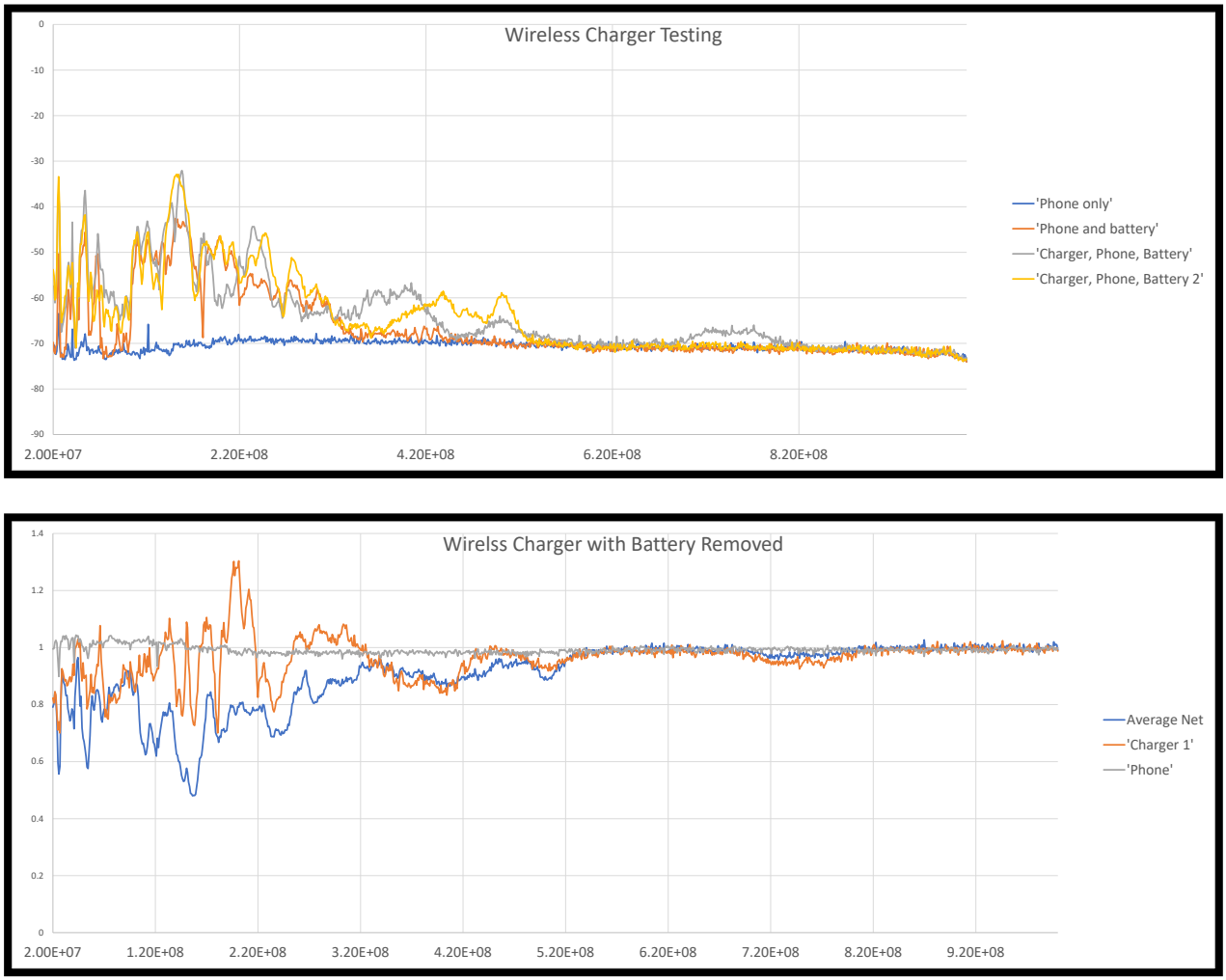

Figure 16. Results of testing a wireless charging system. Here it is difficult to separate the effects of the battery (used to power the charger) with the effects of the charger itself. Data is taken across the 20 MHz - 1 GHz range.

7 7.2-7.3 GHZ UNINTENTIONAL(?) TRANSMISSIONS

During the course of testing on chamber day, a few of the devices tested were found to have unexpected transmissions in the 7.2-7.3 GHz range. These included all phones tested as well as both 'smart' watches (the Apple Watch and the fitness watch). The transmission was not consistent, making it challenging to determine if it was associated with any one mode of the different equipment tested. The signal, as captured in the 1-18 GHz sweep, for the iPhone 12 and 15, are shown in Figure 17. We are currently unsure as to the origin and reason for this transmission.

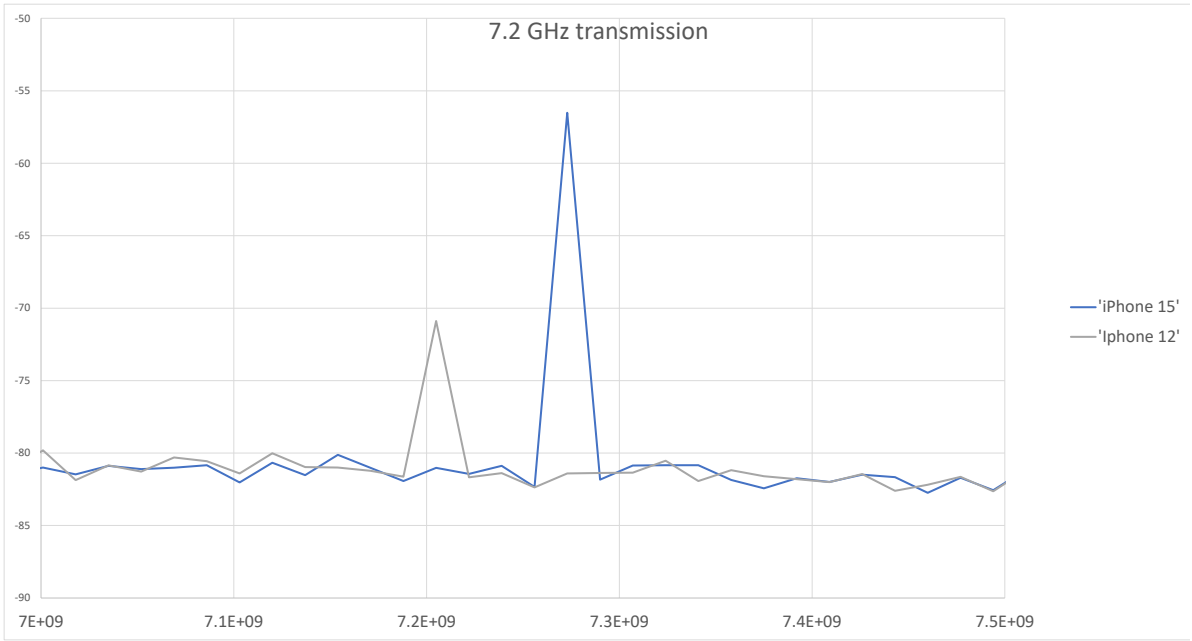

Figure 17. 7.2 GHz transmission from two of the devices tested.