Introduction:

360°RF was retained to independently test four point-to-point 4.9 GHz public safety radio systems manufactured by a leading brand for performance versus published specifications. Further, 360°RF analyzed and/ or tested these devices' construction, circuitry, harmonics and microphonics, leads, materials, and solder joints.

Equipment and Initial Observations

The following itemized equipment was submitted for testing:

Model Number	Serial Number	Description
ODU-1	Omitted	ODU (Radio)... omitted
ODU-2	Omitted	ODU (Radio) ... omitted
ODU-3	Omitted	ODU (Radio) ... omitted
ODU-4	Omitted	ODU (Radio) ... omitted
IDU-1	Omitted	IDU... omitted
IDU-2	Omitted	IDU... omitted
IDU-3	Omitted	IDU... omitted
IDU-4	Omitted	IDU... omitted
Cable-1	Omitted	ODU/IDU Cable 4xT1, 100ft
Cable-2	Omitted	ODU/IDU Cable 4xT1, 100ft
Cable-3	Omitted	ODU/IDU Cable 4xT1, 100ft
Cable-4	Omitted	ODU/IDU Cable 4xT1, 100ft
Rack-IDU-1	Omitted	Rack Mount IDU

Upon initial inspection, it became apparent that none of the IDU's is compatible with the ODU's that were shipped. Documentation from the manufacturer[1] specifies that IDU, ODU and cable assemblies are all designed to work with one of two systems: the Ethernet + T1 or 4xT1. All of the ODU's received are designed to transport Ethernet and one T1 signal and the IDU boxes designed to interface with the ODU's that transport four (4) T1's. In addition, the cables that were shipped are also designed for the 4xT1 system and are not compatible with the ODU's provided.

The IDU boxes have no significant electronics and are largely connector/adapter configurations that provide an easy interface between the cable from the ODU and common connections for power and signals. For the purposes of our testing, the IDU's were unnecessary. Since the supplied cables are straight-through cables, we opted to build a DB37 connector arrangement to access the required signals in the ODU system through the 4xT1 cable provided (Cable-x). This consisted of a DB37-F connector with solder-cups and both power and Ethernet cables soldered to the connector.

[1] Documentation available from manufacturer's website, links omitted...

The connections made to the cable provided are as follows:

Signal	ODU Circular connector	Cable-x DB37	Ethernet Cable	Ethernet cable Color
SUPPLY +	12	8		
SUPPLY +	13	7		
SUPPLY -	24	27		
SUPPLY -	25	26		
ETH TX+	4	16	1	White/Orange
ETH TX -	17	34	2	Orange
ETH RX+	5	15	3	White/Blue
ETH RX-	18	33	6	Green

With these connections, the ODUs were powered-up and became accessible through the Ethernet interface.[2]

When initially powered without an RF path to a second ODU, the ODUs appear to ramp up their power to a maximum in an attempt to establish a link. This was the state used to test the maximum power dissipation. When powered using 24VDC, the ODU's draw 1150mA each (27.6W) or slightly above the maximum specification of 25W provided. This does, however, include resistive losses in the 100' of provided cable. The table below summarizes power requirements as a function of voltage input to the ODU. The specifications claim that the ODUs will function down to 18VDC, but in our tests the units failed to generate a carrier somewhere in the 20-22VDC range and current dropped off significantly. In one test, the system was producing RF at 21 VDC @ 1.4A and at a reduced voltage of 20.5VDC, current fell off to 350mA and RF was no longer being generated by the unit.

Voltage Input	Current Draw	Maximum Power Required
24 VDC	1150mA	27.6W
36 VDC	690mA	24.8W
48 VDC	500mA	24.0W

These measurements were consistent across all four ODU's tested. External case temperature in the lab rose to 37º C during the testing period (23º C ambient).

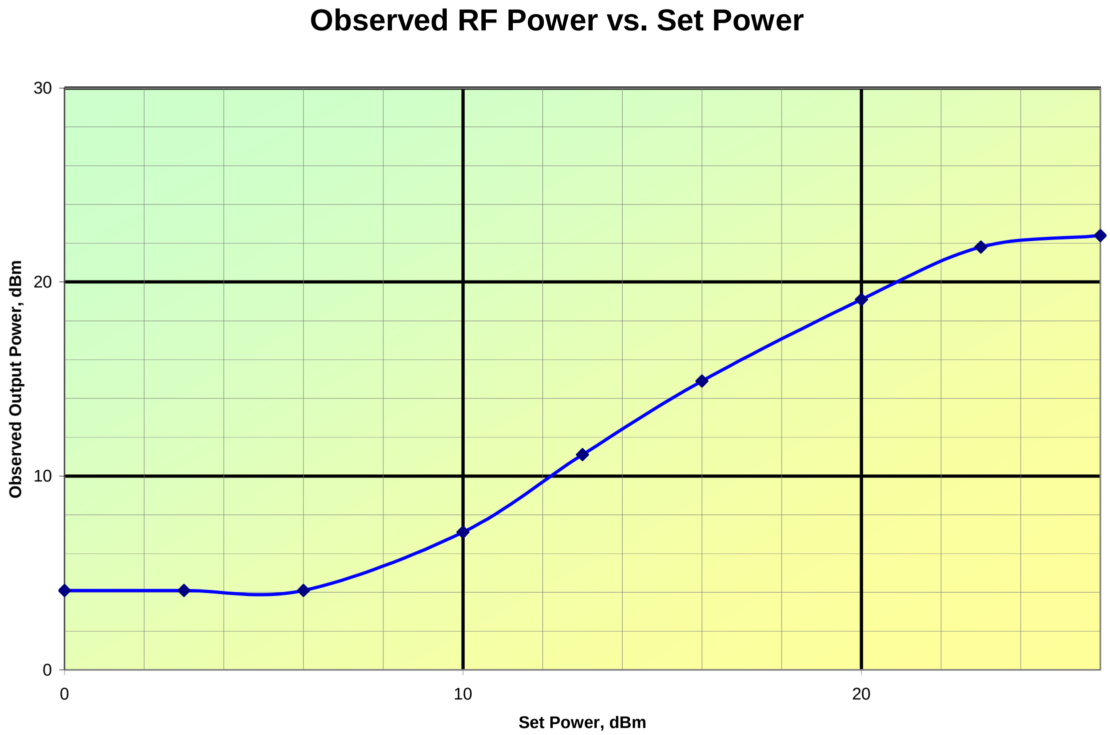
RF Power

Maximum RF output power was observed by enabling the CW carrier in the unit using the following commands:

Set radio cwTone on
Set txPower 23

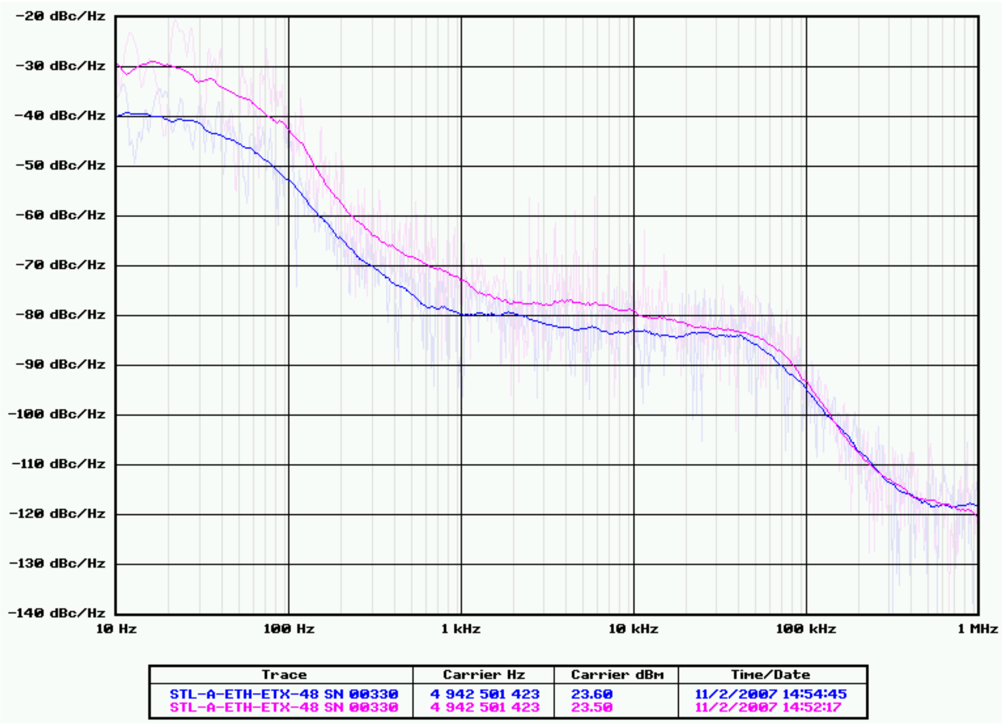
[2] It is possible that use of the wrong cable on an ODU creates a problem that would cause microphonics to appear, but we feel this is unlikely.

Observed power adjustments were reasonably linear if not accurate in the range of +6 to +23 dBm. The graph below is for ODU serial number ODU-4. All units were observed to have similar performance.

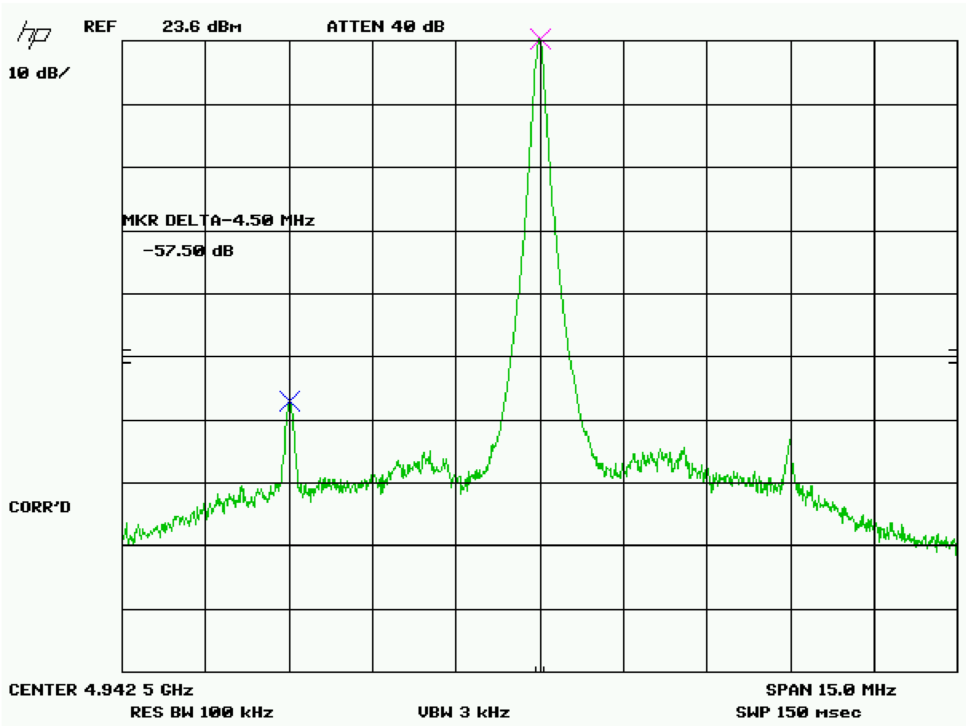


Phase Noise and Harmonics

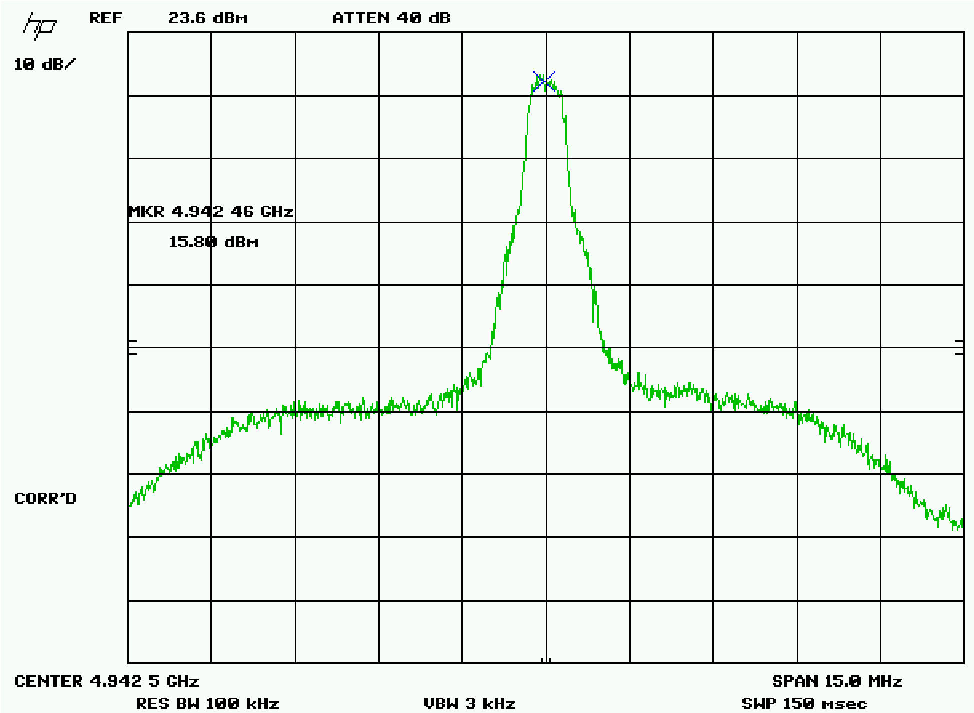
Next, we looked at the phase noise performance of the CW tone produced by the ODU. In the plot shown below, the top line (purple) was taken while the case was subjected to repeated vibration on the exterior of the radio's case (metal tools drug along the heatsink ribbing). The lower line (blue) shows the phase noise when no external vibration was added. There is roughly a 10 dB difference in phase noise from 10 Hz to 1 kHz when external case vibrations are present. This test was repeated three times on the ODU-4 serial number unit with similar results each test, indicating the presence of microphonic coupling.

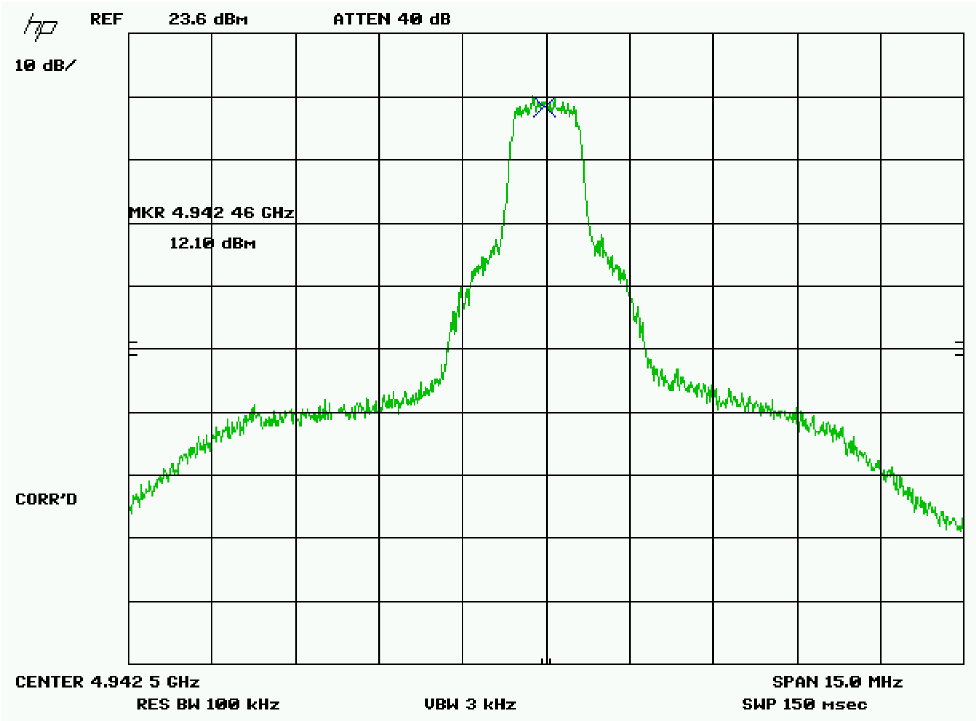


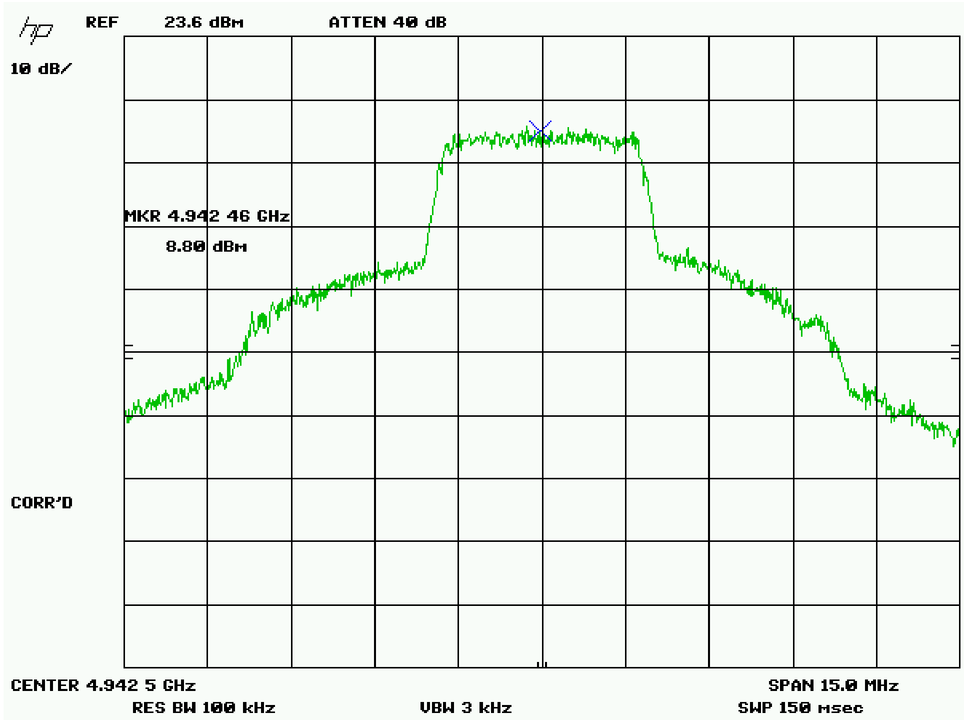
The plot below is of the ODU-4 unit with CW tone on and maximum power output selected. With the radio on channel 3 (4.9425 GHz), we checked for harmonic energy at 9.885 GHz and 14.8275 GHz. No harmonics were detectable down to the noise floor of our analyzer. Two sideband signals were present in the CW analysis at +/- 4.5 MHz with the lower sideband being the strongest at -57.5 dBc (see secondary marker in CW plot).



The following are spectrum displays of radio ODU-4 at 1 MHz, 2 MHz and 5 MHz bandwidth respectively. Bandwidth was adjusted using the on-board configuration software in the ODU through the Ethernet port.

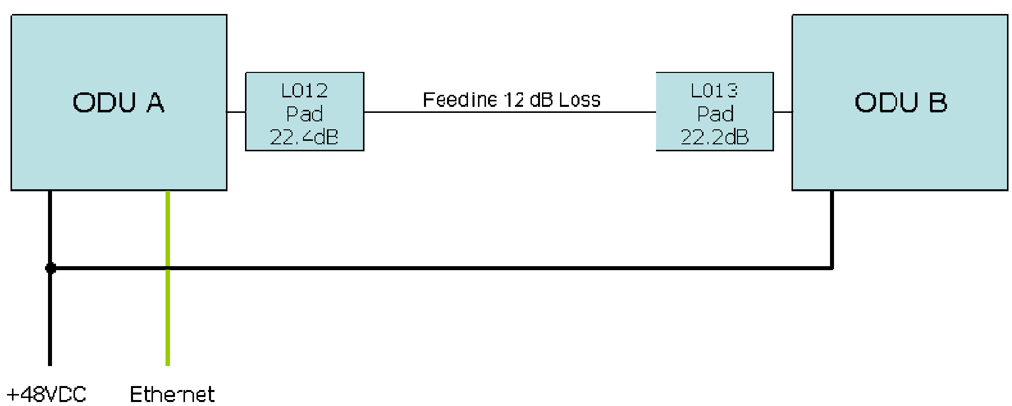


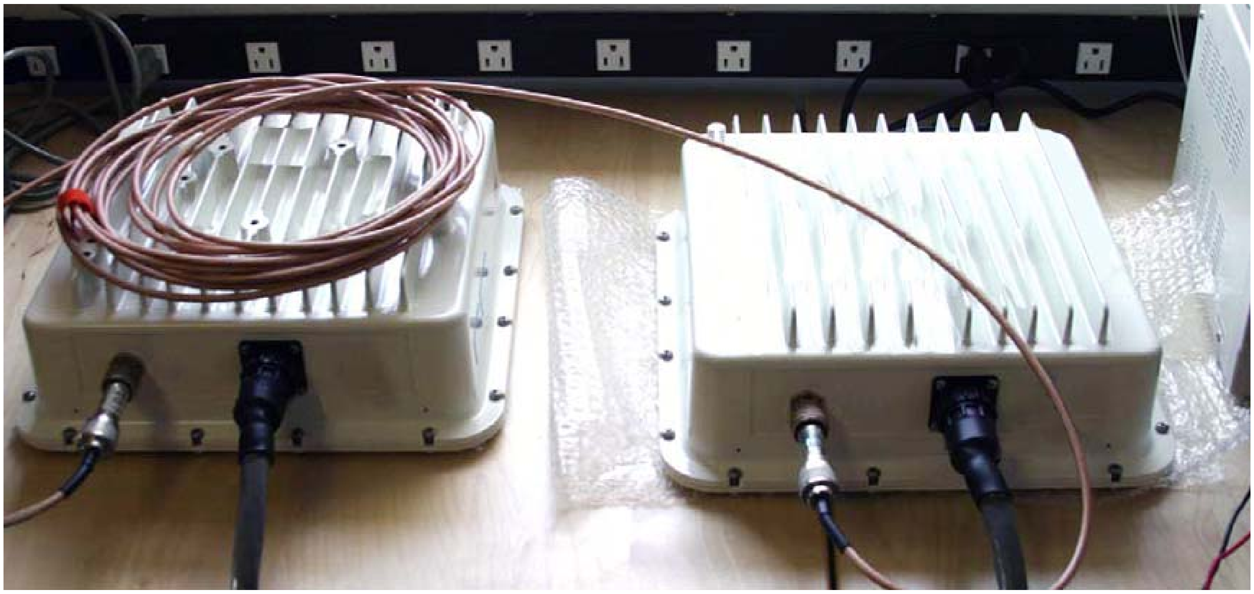




Microphonics

Next, two units were connected together with 56.6 dB loss between the two units to determine if any microphonic effects were present (see diagram and photo below). 56.6 dB insertion loss guarantees a strong signal so that any errors introduced would not be path-related. Both units were placed on the same table and powered from the same power supply at 48 VDC. After two units were connected, power was applied, and five minutes of settling time was allowed, all BER counters were reset, and the modems were watched for an additional five minutes. In all cases, no errors were observed. Both units were set to the 1 MHz bandwidth setting and automatic power adjustment. The units were placed on two layers of small bubble wrap to insulate them, physically, from each other and the work surface. When gently tapping on the work surface, no correctable or uncorrectable errors were reported by the ODU software.





When the tapping was moved to the outside of the case itself, however, errors were reported with each tap of the case. Sometimes the errors were corrected in software by the forward error correction, but often they were not correctable error bursts.

Serial numbers ODU-3 and ODU-1 were connected for the first series of tests while serial numbers ODU-4 and ODU-2 were connected together for the second test series.

Each of the four units was then systematically tested for susceptibility to physical vibration on the exterior of the case. Two types of vibration tests were performed. In the first type, a single tap of a screwdriver to the exterior of the case (heatsink side) was made and then any errors were retrieved from the modem software. This test was performed three times for each radio (ODU). After each test, the counters in the modem software were reset with the command "SET MODEM BER CLEAR YES." The results of this test are shown in the following tables.

ODU-3		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	8192	0
2	4096	0
3	4864	0

ODU-4		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	0	2304
2	1280	4096
3	1280	1792

ODU-1		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	3328	0
2	2816	1792
3	6144	0

ODU-2		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	768	256
2	1024	0
3	12544	0

Each of the radios reported errors due to vibrations on the external case.

Next, each radio was presented with an approximately 500ms burst of physical vibration by dragging a screwdriver over the length of the heatsink of the radio. In all cases, significantly more errors were observed. At the conclusion of each individual test, the BER counters were reset. Each radio was tested in this manner three times. The results of these tests are shown in the tables below:

IDU-1		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	34816	4864
2	32000	13568
3	4294936320[3]	3072

ODU-4		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	1792	7680
2	2048	8704
3	1536	9216

ODU-1		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	28416	9728
2	39424	11776
3	22528	15872

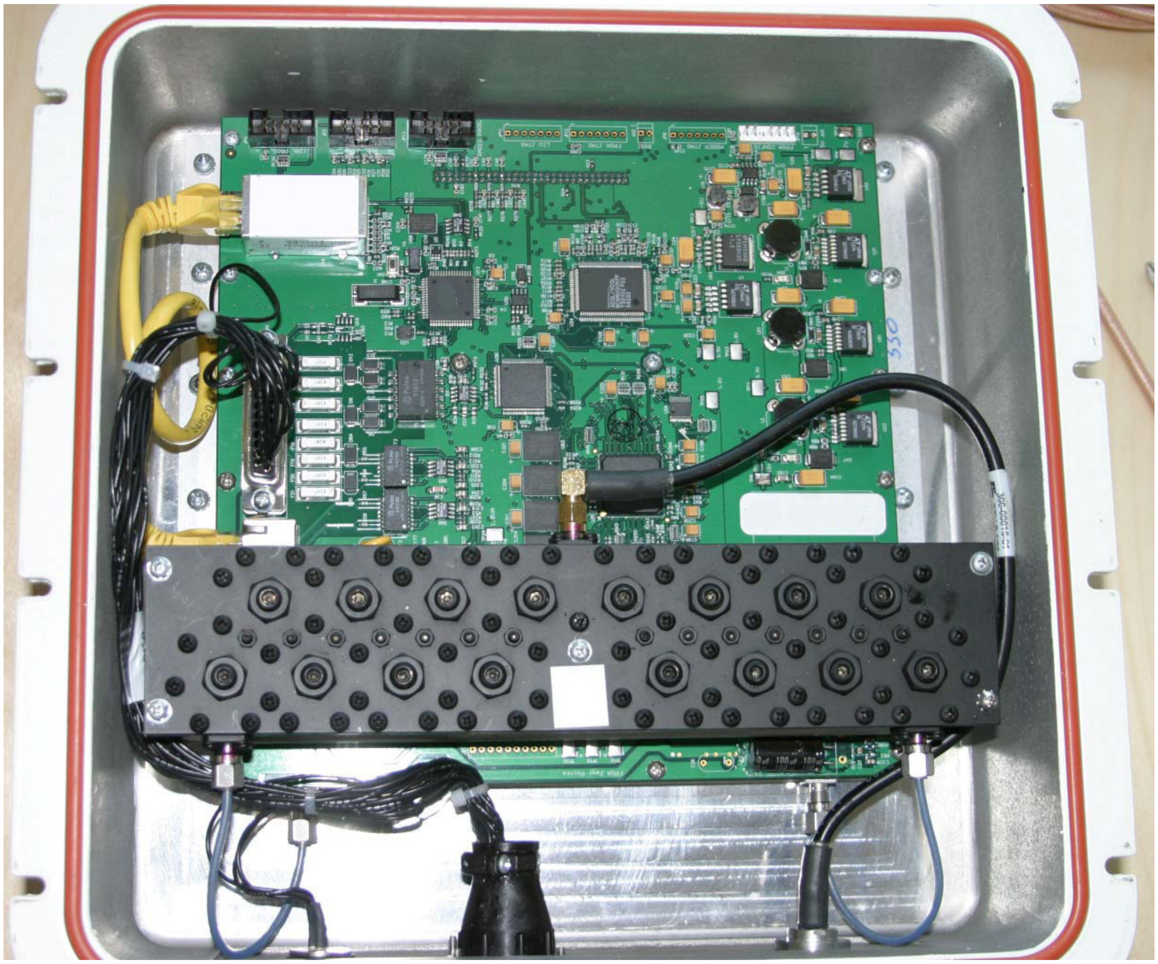
[3] This number is not a typographical error and is the actual number of errors reported by the modem module in the ODU software.

ODU-2		
Test Number	**Reported Corrected Errors**	**Reported Uncorrected Errors**
1	4864	19968
2	9472	17664
3	14848	5888

Again, each radio showed a susceptibility to microphonic noise proportional to the duration and severity of the noise presented.

Next, the case was removed from both the ODU-3 and ODU-4 units for internal examination and to run further tests. The radios appeared to be well constructed both mechanically and electrically. Internal grounding was achieved through direct contact of the PCB with metal surfaces where solder mask was not present as well as through a ground lug to the exterior case. The unit is divided into two main printed circuit boards: one for control, logic and data, and the other for RF. The control board faces up in the case and an IDC connector on the rear of this board connects with a mating IDC connector on the rear of the RF board, which is mounted face-down in a machined aluminum block with individual cavities for RF sections. The RF board is secured to the milled aluminum enclosure with 55 screws, but no additional RF shielding is provided. Both the control and RF boards appear to be multilayer FR4. All solder joints appeared to be well formed. The entire assembly of two PCB's, diplexer and aluminum substrate is directly mounted to the external case without any cushioning.

Two small bursts of errors were taken when the case lid was removed and the unit was turned over, open. The ODU did not register any additional errors while it was sitting idle, open. A photo of the interior of the unit is shown below.



Again, a similar test of tapping a screwdriver on the outside of the case was performed and in each case, errors were registered. The error size was roughly equivalent to the errors taken in the “tap test” above, indicating that the microphonics observed do not appear to be affected by the position of the case lid.

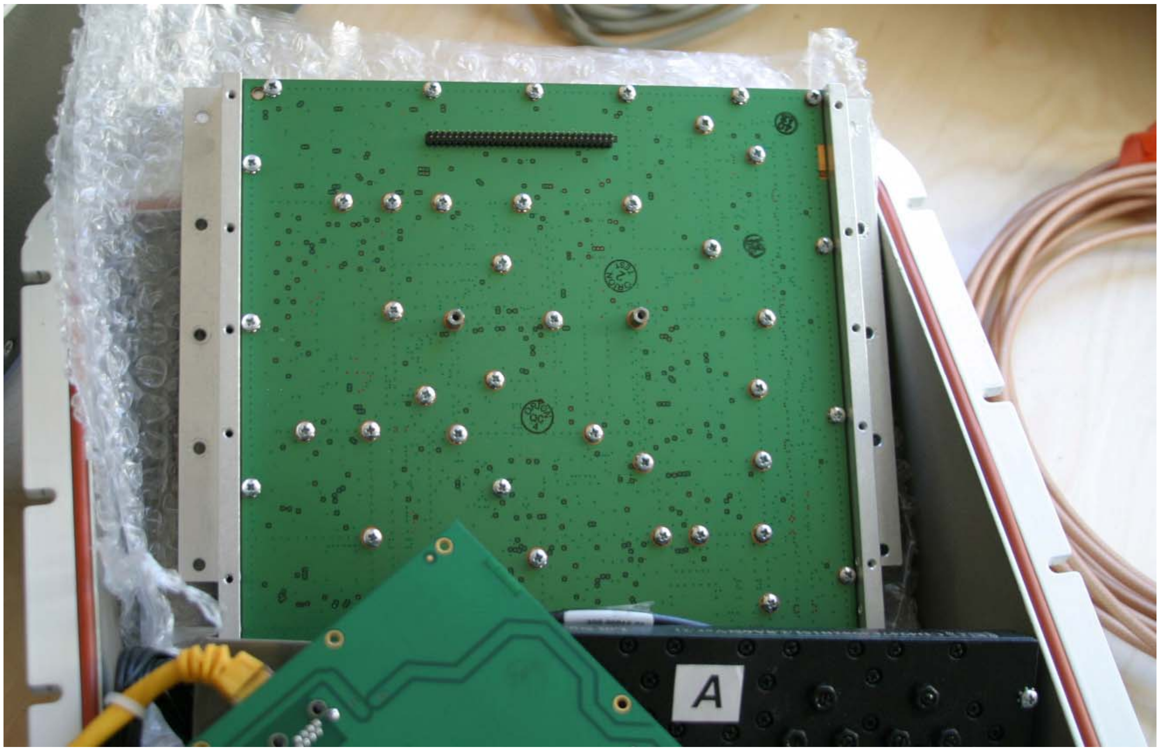
Next, we removed the eight screws that held the entire assembly to the case, removed the assembly and placed two layers of small bubble wrap between the assembly and the interior of the case. The cover was set back on top of the unit, the units were powered up, and the RF path was again established with 56.6dB of attenuation. Both ODU’s (ODU-3 and ODU-2) were given five minutes to warm up and stabilize before running further tests.

The “tap test” was run again with similar results as before. Next, the unit was pulled slightly from the enclosure and rested on the edge of the enclosure with bubble wrap mechanically isolating the assembly from the enclosure (see photo below).

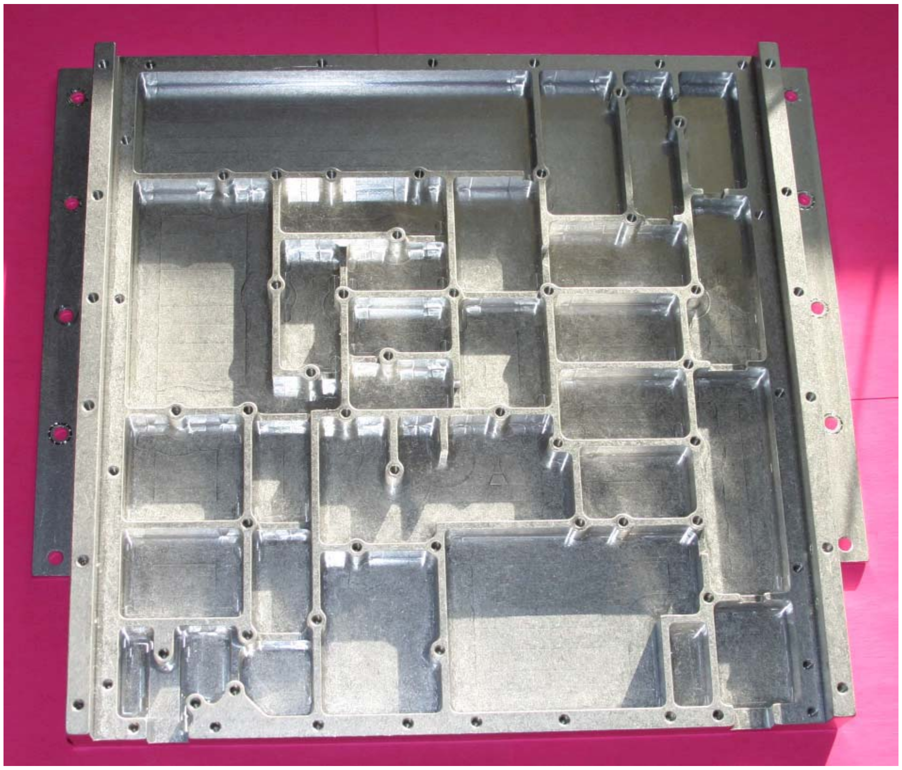
The “tap test” was again repeated, but this time *errors were not registered unless the tap intensity was significantly increased*. This result indicates that some mechanical isolation between the assembly and the case would reduce the effects of the microphonics.

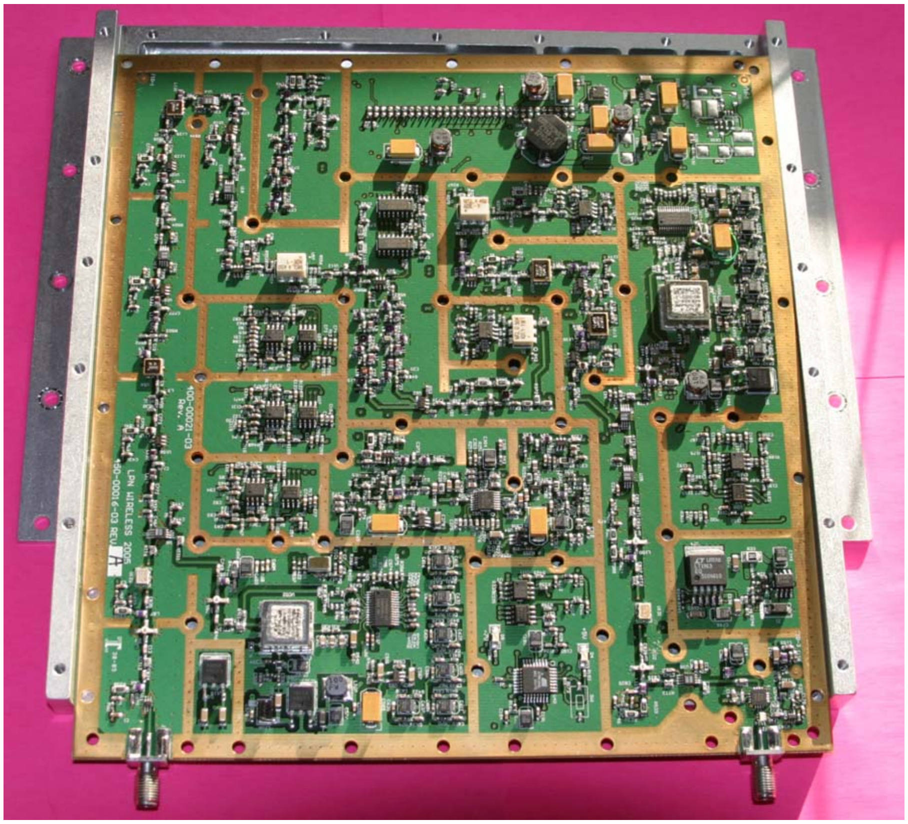
Construction

Next, the duplexer and control PCB were removed from the aluminum housing to expose the RF board. The RF board is inverted into the machined aluminum housing and held in place by 55 screws and four stand-offs (see below).

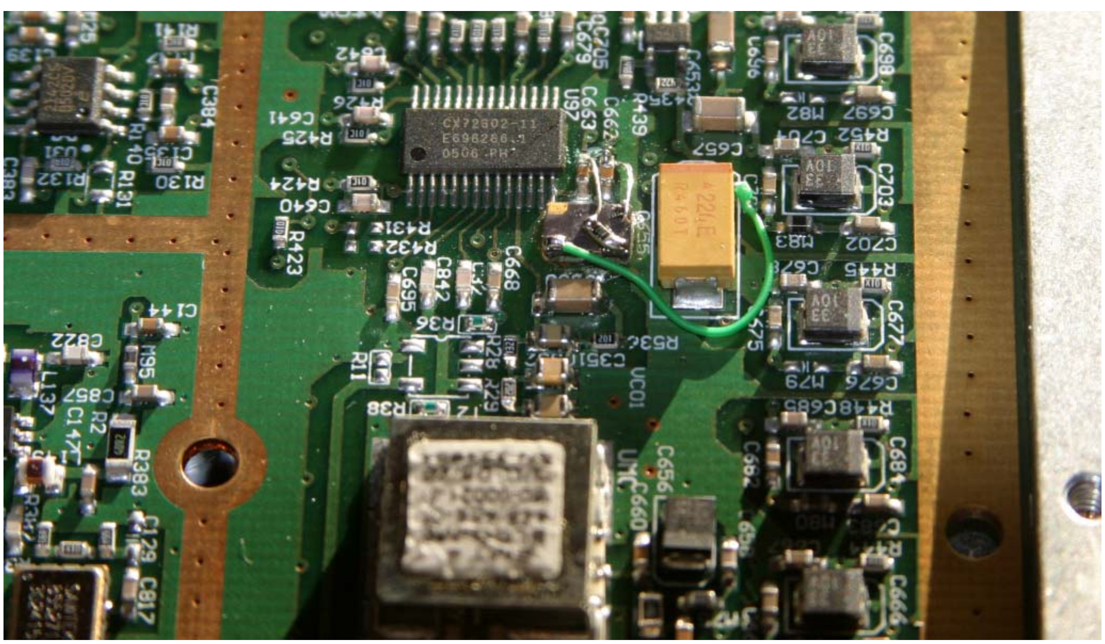


All of these screws were removed and the RF board as examined in further detail (see photos below).





The left side of the RF board, as seen above, is the receive section while the right-hand side is the transmit section. Two VCO's (metal can with white label) can be seen in the photo: one on the lower left, and one in the mid to upper right-hand side. The board appears well constructed and the quality of assembly including soldering appears excellent. Just above the transmit VCO, some rework has been performed as shown in the next photo: a device has been glued to the PCB dead-bug style and passive components and a green wire are hand-soldered to the device.



After observations, the ODU was reassembled and retested for correct function.

Summary

All four units appear to be well constructed with proper attention given to separation of RF and digital functions, grounding and sturdiness. The units matched the specifications provided. All four units did, however, exhibit what we would consider moderate microphonic susceptibility. It is our opinion that these units would probably not suffer from localized rain as an microphonic source. Other mechanical vibrations such as the shimmy of a pole in the wind or any metal-on-metal vibrations would likely induce noise sufficient to generate error conditions, however. A comprehensive analysis of path attenuation versus error rate, and/or to determine the threshold for errors due to different stimuli, can be conducted at additional cost.

The microphonic condition could be caused by any of a number of design issues. Common problems include local oscillators, themselves, SAW filters and resonant cavity effects. Soldering problems are also a possible contributing source; but it is less likely that all four units have the same manufacturing flaw, and much more likely that they share a common design flaw.