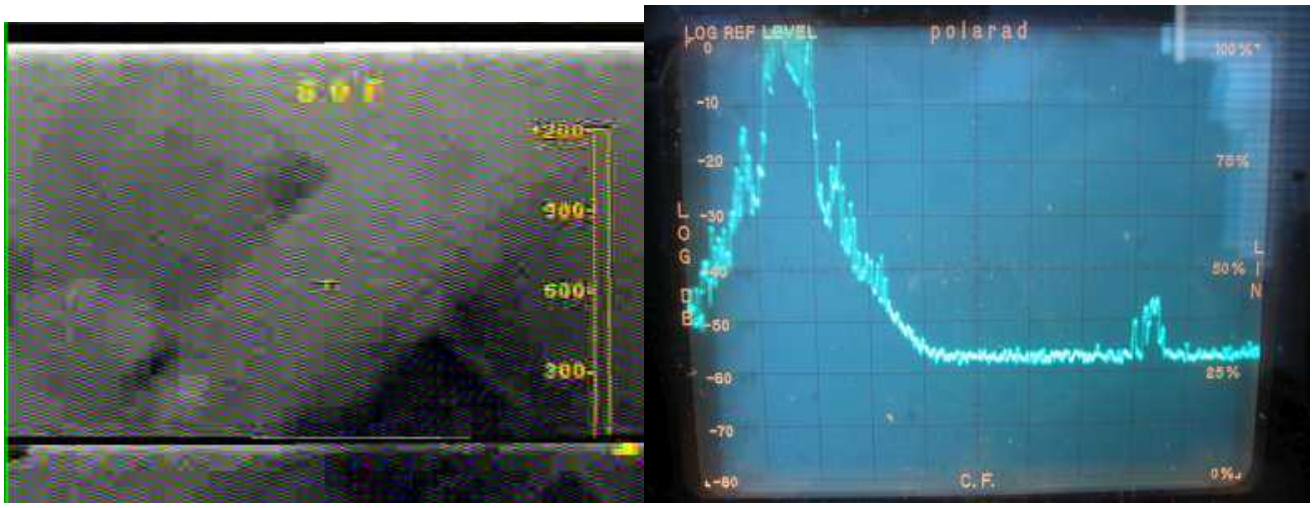
Digital Firefighter Payload Radio-Frequency Interference Spectrum Analysis



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Introduction

The video snapshot on the cover page illustrates the current interference problem on the digital firefighter (DFF) payload. The interference becomes worse as bit rate increases, which links the problem to the 2.4GHz to 900MHz frequency-converter amplifier (FCA). The frequency of video corruption is directly related to the frequency of packets sent through the FCA. Because of the close proximity of the analog video link (AVL) to the FCA digital link, both spatially and spectrally, radio-frequency interference (RFI) is suspect. I used a Polarad model 632C-1-6 2GHz spectrum analyzer in peak mode and a small SMA antenna to perform measurements. After performing measurements in several system configurations, RFI is small, but seems present.

802.11 Radio Channel Selection

The following two measurements were taken with the payload functioning and the 802.11 radios operating on channel 1, which is the input to the FCA. You can clearly see that the output of the FCA trails off to the noise level by 950MHz, well before the 1040MHz of the AVL. You can also see that the FCA is operating outside of the ISM band at about 885MHz, which cannot be tolerated.

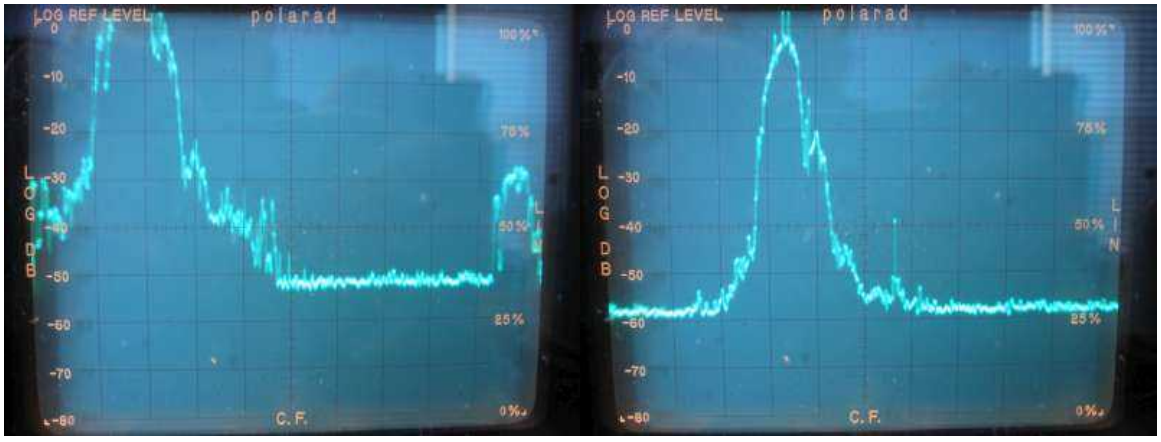

Illustration 1: 0950MHz -30dBm 20MHz/div 802.11 Channel 1

Illustration 2: 0915MHz -10dBm 20MHz/div 802.11 Channel 1

The following two measurements were taken with the payload functioning and the 802.11 radios operating on channel 7, which places the bulk of the FCA energy back into the ISM band.

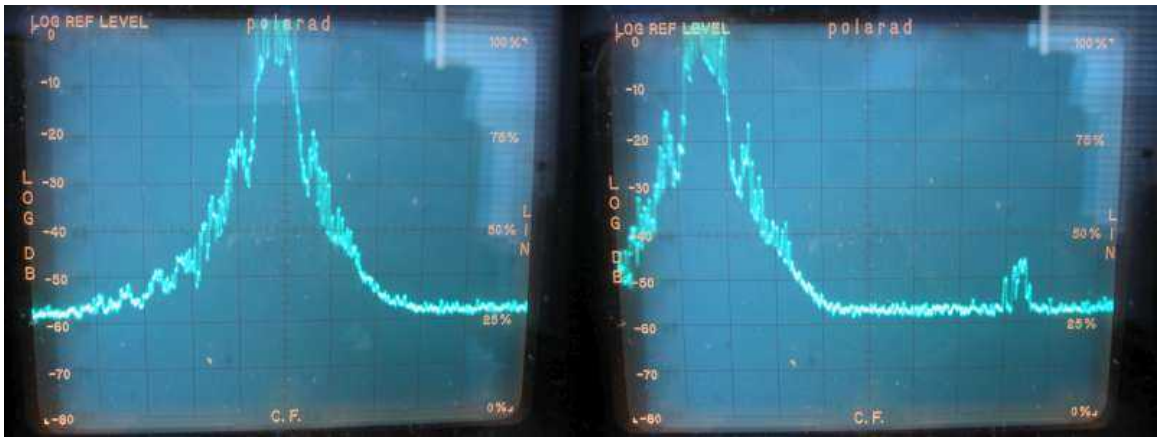

Illustration 3: 0915MHz -10dBm 20MHz/div 802.11 Channel 7

Illustration 4: 0975MHz -10dBm 20MHz/div 802.11 Channel 7

Spectra With and Without AVL

The following two measurements show the payload operating with and without the AVL. This illustrates the amount of FCA energy present in the AVL channel 4 band. It also illustrates the center frequency near 1040MHz (ch 4) and the bandwidth of the AVL signal.

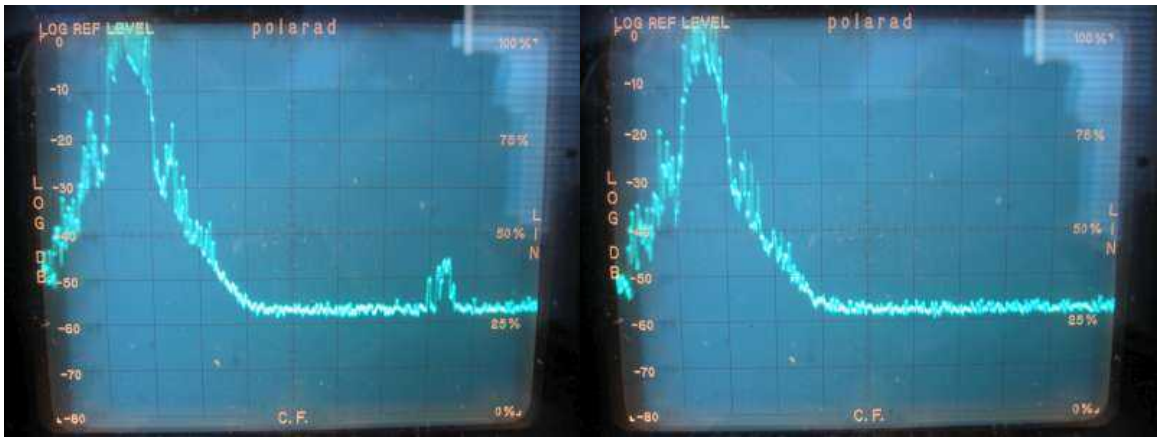

Illustration 5: 0975MHz -10dBm 20MHz/div 802.11 Channel 7 AVL TX On

Illustration 6: 0975MHz -10dBm 20MHz/div 802.11 Channel 7 AVL TX Off

AVL Spectra With and Without High Data Throughput

The following measurements were taken with the AVL TX on, with and without the payload software transmitting MPEG video, and with and without scene motion. The MPEG data rate was set to 2Mb/sec. The spectrum in and near the AVL channel 4 band changes when a high data rate is sent through the FCA. The last shot shows the AVL band when a large amount of scene motion is present. I can come up with two possible explanations for this behavior at this point. The first is actual RFI from the FCA overlapping with the AVL band; such as a harmonic. The second is power supply voltage fluctuations causing the AVL TX output to change. Power draw fluctuation caused by the FCA going into TX mode could cause voltage fluctuations to the AVL TX. In my test setup everything is powered by the payload power supply. The FCA, camera, AVL TX, and AVL RX are all powered by the payload 12V supply. Measuring power fluctuations at this speed is beyond the range of my portable hand-held oscilloscope. I will perform better power measurements in the future with a better oscilloscope.

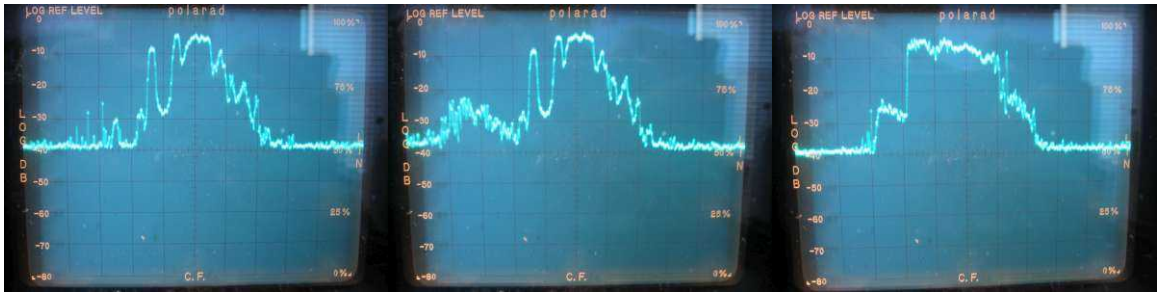

Illustration 7: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 MPEG TX Off No Scene Motion

Illustration 8: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 MPEG 2Mb TX No Scene Motion

Illustration 9: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 MPEG TX Off Scene Motion

AVL Band During File Transfer

The following shots show the AVL 1040MHz channel 4 band in three different configurations. These configurations were chosen to eliminate the AVL TX and power fluctuations from the possible causes of interference. These shots prove that the RFI is actually harmonics from the FCA and not something else.

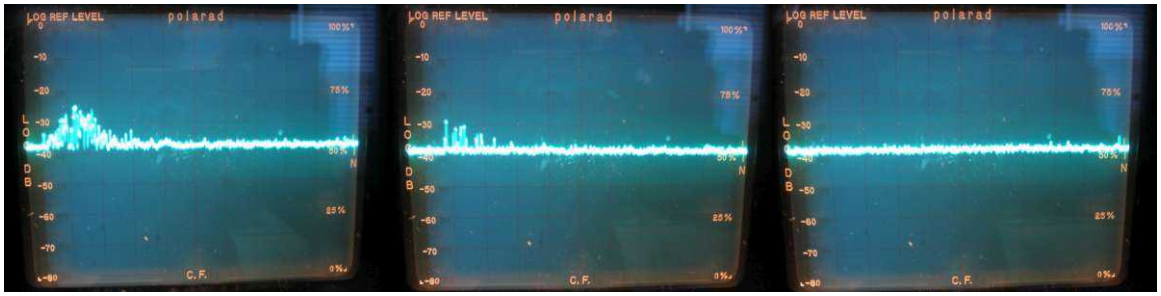

Illustration 10: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 Payload On AVL TX Off Large File Transfer

Illustration 11: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 Payload On AVL TX Off Idle No Transfer

Illustration 12: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 Payload Off AVL TX Off

Baseline Site Survey

The following two shots show the AVL channel 4 band spectrum and ISM band spectrum with the payload and ground station off. These baselines were taken using peak detection over a period of 10 minutes with 10ms per scan. These two shots help eliminate other sources of RFI from the previous measurements.

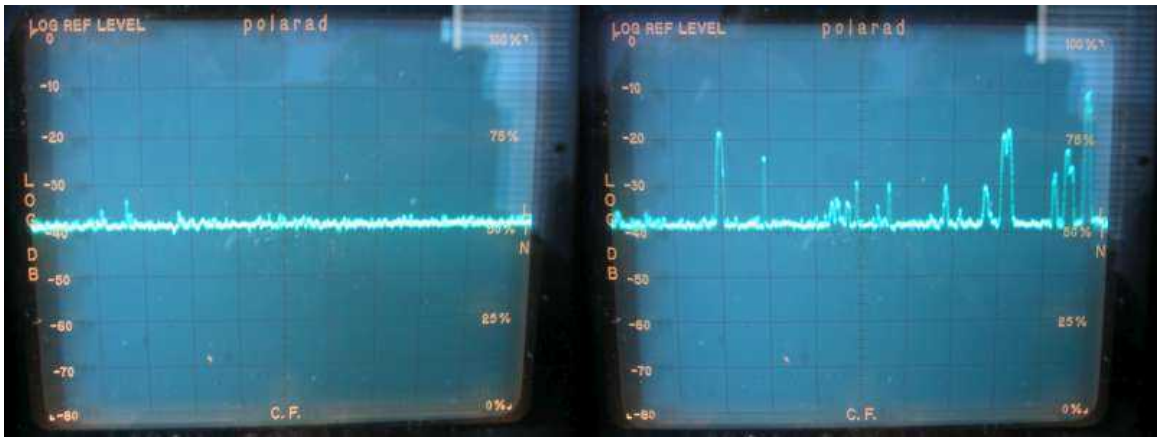

Illustration 13: 1040MHz -50dBm 05MHz/div 802.11 Channel 7 Payload & GS Off

Illustration 14: 0915MHz -50dBm 05MHz/div 802.11 Channel 7 Payload & GS Off

Conclusions

The 802.11 radios should be operated on channel 7 as stated by the FCA manufacturer. The spectrum in the AVL band changes when a high data rate signal is transmitted through the FCA. The FCA harmonics are causing RFI with the AVL channel 4 band at 1040Mhz. Other harmonics are present on other AVL channels. A low-pass filter on the FCA output or an alternate AVL frequency should help.