NICST_MEMO_08_010

NICST Internal Memo

Date: March 18, 2008
From: J McIntire, C. Pan, and T. Schwarting
To: Bruce Guenther, Jim Butler, Jack Xiong
Subject: Analysis of VIIRS FU1 FP-13 point-to-point crosstalk for SMWIR and LWIR focal planes

----

References:

[1] "Analysis of VIIRS FU1 FP-13 point-to-point crosstalk for SMWIR", NICST_MEMO_08_004, J. McIntire, C. Pan, and T. Schwarting, January 28, 2008
[2] "DAWG Standardized Crosstalk Units (Version 1.0)", C. Fisher, October 26, 2007
[3] "Sensor Performance Verification Plan (PVP) – VIIRS"
[4] "FP-13 Shutter Phase Determination", C. Fischer, December 26, 2007

1. Introduction

VIIRS FU1 FP-13 ambient phase II includes a comprehensive crosstalk test. This work is concerned with the static point-to-point crosstalk tests for the SMWIR and LWIR bands in FP-13. Some analysis of the static point-to-point crosstalk tests for the SMWIR bands is contained in [1]. The illumination sources used here were the TMC BB, TMC SIS, and ScMA. Bandpass filters (BPF) were utilized to insure that each UAID has a unique sender band and to minimize optical scattering. For each collect, a reticle was used to fully illuminate one detector. Every collect contains 16 scans (in diagnostic mode), forming a pattern of two consecutive scans with the shutter open followed by two consecutive scans with the shutter closed. The low gain mode used Default DPP & M16B APID band substitution tables and the auto gain mode used M16A DPP & APID tables / Default DPP & M16B APID tables. Optical scattering and point-to-point crosstalk are obtained by examining the influence coefficients in dn, radiance, and noise space.

Tables 1 and 2 list the following test configuration information for the SMWIR and LWIR bands respectively: UAID, number of collects, gain mode, filter utilized, source type (TMC BB, TMC SIS, or ScMA), and source irradiance. The focal plane layouts are shown in Figure 1.

2. Data processing

The data analysis required here is partially presented in [1]. The background subtracted dn and the influence coefficients in dn, radiance, and noise (government standard) spaces,

$$XF_{dn} = \frac{dn_{REC}(i)}{dn_{SND}(j)}, \qquad (1)$$

$$XF_L = \frac{\Delta L_{REC}(i)}{\Delta L_{SND}(j)} = \frac{g_{SND}(j)}{g_{REC}(i)} \frac{dn_{REC}(i)}{dn_{SND}(j)}, \quad (2)$$

and

$$CNR = \left[\frac{L_{MAX}(j) g_{SND}(j)}{2}\right]\left[\frac{dn_{REC}(i)}{dn_{SND}(j)}\right]\left[\frac{\sqrt{3}}{\sigma_{REC-DARK}(i)}\right], \quad (3)$$

respectively, are discussed in [1]. Here dn_{SND} is the dn of the sender detector, dn_{REC} is the dn of the receiver detector, g_{SND} is the radiometric gain of the sender detector, g_{REC} is the radiometric gain of the receiver detector, L_{MAX} is the maximum radiance for the sender band and $\sigma_{REC\text{-}DARK}$ is the standard deviation of the receiver detector for the shutter closed scans only. The i's and j's indicate the gain state of the quantity in question. All SMWIR and LWIR bands except M13 are single gain, so consideration of different gain states is only necessary in cases involving band M13. Note that the factor of $\sqrt{3}$ is included only for diagnostic mode in order to facilitate comparisons with the aggregation mode; however, this factor is not included if the receiver band is M13, as no aggregation is performed for dual gain bands. A detector meets the government standard if the absolute value of CNR is less than 1 [2].

In addition, we will also compare the data to the specifications in the PVP document [3], by including an alternate measure of the crosstalk strength. The requirement in [3] states that the crosstalk should be compared to the greater of half the Noise Equivalent dL (NEdL), given by

$$\frac{1}{2} NEdL = \frac{\sigma_{REC-DARK}}{2\sqrt{3} g_{REC}}, \quad (4)$$

and $0.002 L_{TYP}$. Thus, the PVP standard (normalized to 1) for crosstalk strength is the lesser of the following:

$$PVP_{Spec} = L_{MAX}\left[\frac{g_{SND}}{g_{REC}} \frac{dn_{REC}}{dn_{SND}}\right]\left[\frac{1}{0.002 L_{TYP}}\right] \quad (5)$$

and

$$PVP_{Spec} = 2 L_{MAX} g_{SND}\left[\frac{dn_{REC}}{dn_{SND}}\right]\left[\frac{\sqrt{3}}{\sigma_{REC-DARK}}\right]. \quad (6)$$

The PVP standard is met (i.e. there is more noise than crosstalk) if the absolute value of PVP_{Spec} is less than 1. As with CNR, the factor of $\sqrt{3}$ is not included if M13 is the receiver band. For the purposes of this work, we will consider both CNR and PVP_{Spec}.

These coefficients give us an idea of the point-to-point crosstalk strength. CNR and PVP_{Spec} are used to determine whether an influence coefficient is crosstalk or noise; the larger the CNR (or PVP_{Spec}), the more crosstalk is contained in the signal.

For the LWIR bands, we must also consider the problem imposed by band substitution; if a sender band has been excluded from the reported data, then the shutter order cannot be determined as in [1]. The band substitution tables used here are listed in Table 3. In the case where band M16A is the sender, optical scattering from M16A to M16B provides enough of a difference between shutter open and closed in the latter band that the shutter order may be determined. However, this method is inadequate to recover the shutter order when either M14 or M15 is the sender. In [4], a method for solving this problem was proposed; the shutter phase was determined by the Fast Fourier Transform of the maximum value of the detectors for each scan. The results indicate that the probability that the shutter order will reset increases as the time between collects increases. The probability that the shutter order changed was small for sender bands M14 and M15, so by determining the number of scans between collects, one can determine the shutter order of a collect whose sender band is not recorded due to band substitution.

There is a large amount of optical spillover in-track for each band. This is not crosstalk, so in order to remove this effect, we replace the influence coefficients N detectors from the sender in both track directions with an average of the influence coefficients over the remaining detectors. The following are the numbers used for the bands in question: N=3 for M15, M16A, M16B, and I5; N=4 for M9, I3, and I4; N=5 for M8, M10, and M13 in auto high gain; N=6 for M11, M12, and M14; and N=7 for M13 in auto low gain and fixed low gain. In this way, most of the in-track optical spillover was removed.

The point-to-point crosstalk coefficients are collected into the point-to-point crosstalk maps (one for each coefficient: XF_{dn}, XF_L, CNR, and PVP_{Spec}). The point-to-point coefficients for a given sender band and detector are averaged for each receiver band. Due to the fact that the detectors in the SMWIR and LWIR bands are staggered, the point-to-point coefficients are also averaged for odd and even detectors separately in each receiver band. Both the band averaged and odd-even averaged coefficients are collected into their own crosstalk tables. Figures 3, 5, 7, 8, 10, and 12 plot XF_{dn} for every detector in the LWIR bands. Figures 2, 4, 6, 9, and 11 plot the odd-even averaged government standard influence coefficients for all LWIR bands.

3. Analysis - LWIR

Figures 2 – 8 show the effects of optical scattering in the LWIR bands. Figure 2 graphs the odd – even receiver detector averages for each sender detector in band M16B; there is stronger optical scattering from M16B into bands M16A and I5 (the subsamples are considered separately). Note that M16A even receives noticeably more optical scattering than M16A odd (Figure 3).

This odd – even detector difference is related to the geometry of the focal plane layout, shown in Figure 1. In the scan direction, an even detector in the sender band is closest to the corresponding even detector in the adjacent band; however, an odd detector in the sender band is closest to the nearest even detectors in the adjacent band. Thus, geometry dictates that optical scattering from M16B will be stronger in M16A even. This is seen in Figure 3, where it is clear that M16A even has a stronger signal.

The influence of geometry is also seen in Figures 4 and 5 when M16A is the sender band and I5 is the receiver band. The reverse is the case for the opposite scan direction (i.e.

M16B odd has a stronger signal), which describes the optical scattering from M16A to M16B in Figures 4 and 5. Figures 6 - 8 show a small amount of optical scattering from sender band I5 against the scan direction to M16A.

Sub-sample difference is evident and is observed in I5 from sender bands M16A and M16B, as shown in Figures 2 - 5. Note that even and odd detectors behave similarly for a given sub-sample, as shown in Figures 2 and 4.

Band I5 detector 31 frequently records an anomalously large dn as can be seen in Figures 3, 5, 7, 8, 10, and 12. This occurs for all sender bands in LWIR. In addition, the dn from this detector is not always negative, as is seen in Figure 3. This is electronic crosstalk, as it is sometimes negative and occurs some distance from the illuminated detector.

Figures 13 and 14 show the difference between CNR and PVP_{Spec} for sender bands M15 and M16B, respectively. It is clear that PVP_{Spec} is the more stringent requirement, except in the event of optical spillover and spectral overlap. PVP_{Spec} represents a worst case measurement, as seen from Eqs. (5) and (6) in which the crosstalk at L_{MAX} is divided by the noise, whereas CNR represents a typical case measurement, as seen from Eq. (3) in which the crosstalk at L_{MAX} / 2 is divided by the noise.

Figure 15 shows that there is sometimes a small Out Of Band (OOB) response in M16B when M15 is the sender. The CNR values for these detectors are large, but not necessarily greater than unity.

For the LWIR bands, the scans recorded with the shutter closed exhibited a higher background for the illuminated detector than neighboring detectors, by about 50 %. This is due to thermal leakage and as a result the data is contaminated. For example, for a typical scan with the shutter open using the BPF M14 and the reticle over detector 1, the average dn is about 2800; with the shutter closed, the average dn is about 310. When the reticle is at detector 8, the average dn for detector 1 is about 230. This is shown in Figure 19. Because this was a staring test, no other data was available to use as a background subtraction. As a result, the background subtracted dn is underestimated. Therefore, one may conclude that, in consequence of this thermal leak, the influence coefficients given here for the TEB bands are an overestimate (by about 5 %).

4. Analysis - SMWIR

Some of the analysis for the SMWIR bands is contained in [1]. The major conclusions of that work were: optical scattering exists between I3 and M10 (M/I 100% and I/M 100%), I4 and M12 (M/I 100% and I/M 47%), and M13 (flg and alg) to I4 and M12; a large sub-sample difference in radiance space is observed in sender band I3 and to a lesser extent I4; readout crosstalk exists from sender bands I3 and I4 to M8 – M11; small readout crosstalk pairs exist from M10 to M8 and M8 to M10; and crosstalk coefficients appear to vary with gain state, but seem to be more stable with respect to illumination level (insufficient evidence exists to draw any definitive conclusions). Here ahg, alg, and flg refer to auto high gain, auto low gain, and fixed low gain respectively.

For sender band M8, detector 12, data for the receiver bands M12 and M13 is missing. In UAID 3102097, collects 24 and 25 both use the M16A DPP & APID band substitution tables, instead of Default DPP & M16B APID tables andM16A DPP & APID tables, respectively. As a result, this data was not collected (as can be seen from Table 3).

The optical scatter between M13 (flg and alg) to I4 and M12 in [1] was probably OOB response and is a result of the more stringent requirement (PVP_{Spec}). Using the CNR specification from above [2], this OOB response is only of interest from M13 flg to M12.

In Table 4, the detectors that did not meet the government standard for CNR are listed. This does not include those detectors that failed due to spectral overlap, OOB response, and in-track optical spillover. Notice that the sender band for all of these detectors is M13 ahg. The CNR coefficients for M13 ahg are in general larger than that of the other bands considered here, as is seen in Figure 16. The receiver detectors in the M bands listed in Table 4 all had dn values that were higher than other detectors in those bands; the receiver detectors in the I bands listed in Table 4 all had dn values that were among the highest in their respective bands. The noise values for all of these detectors were generally consistent with the other detectors in those bands. Thus, we conclude that these detectors were exhibiting electronic crosstalk. However, it should be noted that while these detectors all have an absolute value of CNR > 1, it is still very close to 1. As a result, these detectors do exhibit electronic crosstalk, but at a level that is slightly above the noise.

Figures 17 and 18 show the difference between CNR and PVP_{Spec} for sender bands M12 and M9, respectively. Again, it is clear that PVP_{Spec} is the more stringent requirement, except in the event of optical spillover and spectral overlap.

Summary

- Optical scattering dominates the crosstalk coefficients. Major optical scattering exists between M16A, M16B, and I5.
- Sub-sample difference in I5 is observed for sender bands M16A and M16B.
- Detector 31 in band I5 exhibits electronic crosstalk.
- Overestimation of influence coefficients is due to thermal leak for LWIR bands.
- Larger crosstalk in general in M13 ahg, a number of detectors fail to meet the government standard. These detectors exhibit only a slightly larger crosstalk than noise level.

Acknowledgement

The sensor test Data used in this document was provided by the SBRS testing team.

Approaches for data acquisition and data reductions, as well as data extraction tools were also provided by the SBRS. We would like to thank the SBRS team for their support.

Table 1: FU1 FP-13 point-to-point crosstalk test configurations for SMWIR bands

UAID	Collects	Gain	BPF	Source	Illumination
U3102097	33	Auto	M8	TMC SIS	7800 ft-Lb
U3102104	36	Auto	M10	TMC SIS	4800 ft-Lb
U3102107	69	Auto	I3	TMC SIS	5200 ft-Lb (1-25) 5000 ft-Lb (26-42) 4900 ft-Lb (43-69)
U3102118	33	Auto	M9	TMC SIS	4500
U3102124	39	Auto	M12	TMC BB	115 C
U3102150	66	Auto	I4	TMC BB	103 C
U3102163	8	Auto	M13	TMC BB	116 C
U3102164	28	Auto	M13	TMC BB	95.5 C
U3102165	57	Auto / Low	M13	TMC BB	405 C
U3102168	49	Auto / Low	M13	TMC BB	598 C
U3102193	33	Auto	M11	ScMA	10.762 A (1-7) 10.491 A (8-12) 11.294 A (13-21) 10.788 A (22-27) 12.2 A (28-33)

Table 2: FU1 FP-13 point-to-point crosstalk test configurations for LWIR bands

UAID	Collects	Gain	BPF	Source	Illumination
U3102128	34	Auto	M14	TMC BB	135 C
U3102155	33	Auto	M16A	TMC BB	201 C
U3102157	33	Auto	M16B	TMC BB	215 C (1-7) 208 C (8-33)
U3102159	64	Auto	I5	TMC BB	165 C
U3102161	32	Auto	M15	TMC BB	175 C

Table 3: FU1 FP-13 band substitution table

Default DPP & M16B APID	M16A DPP & APID
M6	M16A
M12	DNBHGA
M13	DNBHGB
M14	DNBMGS
M15	DNBLGS

Table 4: FU1 FP-13 SMWIR detectors not satisfying government standard

Sender Band	Detector	Reciever Band	Detector	CNR
M13 ahg	4	M10	14	-1.06
M13 ahg	7	M10	7	-1.15
M13 ahg	8	I3 SS1	8	1.01
M13 ahg	8	I3 SS1	19	1.09
M13 ahg	11	M11	8	-1.13
M13 ahg	13	I3 SS2	2	-1.06
M13 ahg	13	I3 SS2	10	-1.03
M13 ahg	13	I3 SS2	16	-1.03
M13 ahg	13	I3 SS2	26	-1.05
M13 ahg	16	M12	4	1.02

Figure 1: Focal plane layouts for LWIR and SMWIR (M16_1 is M16A and M16_2 is M16B in the text)

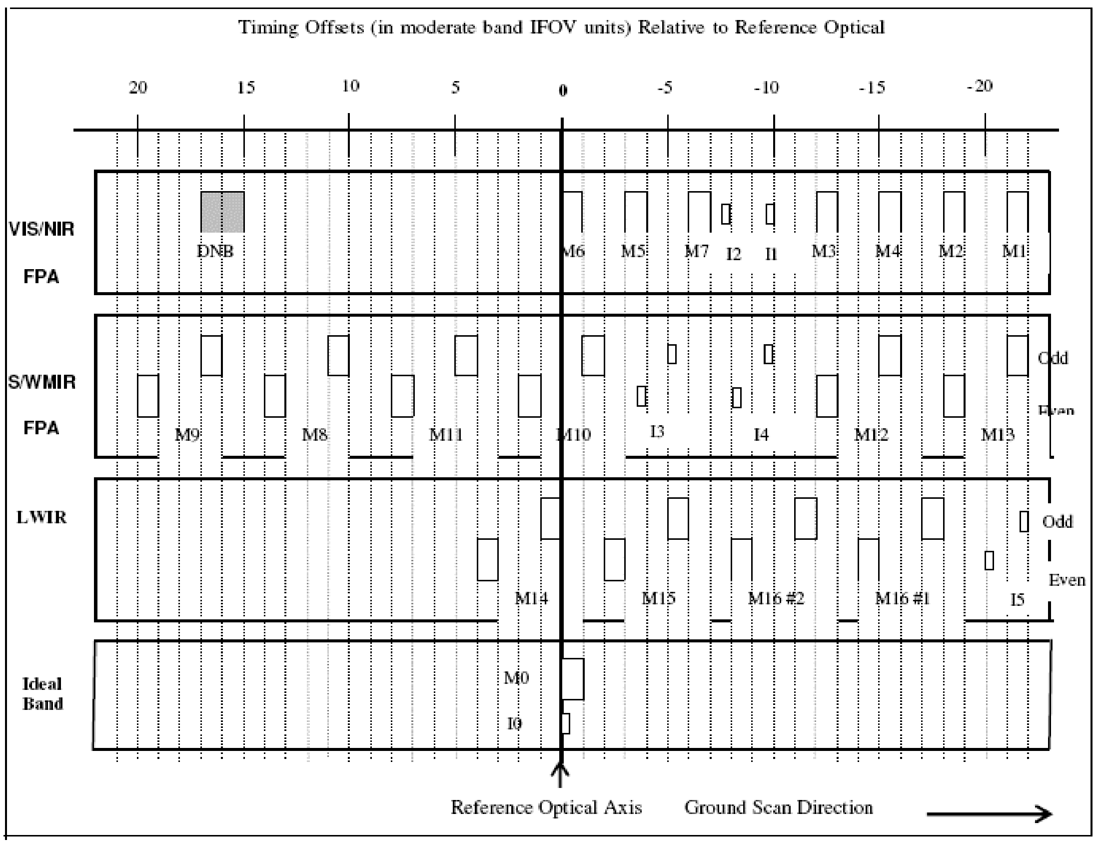
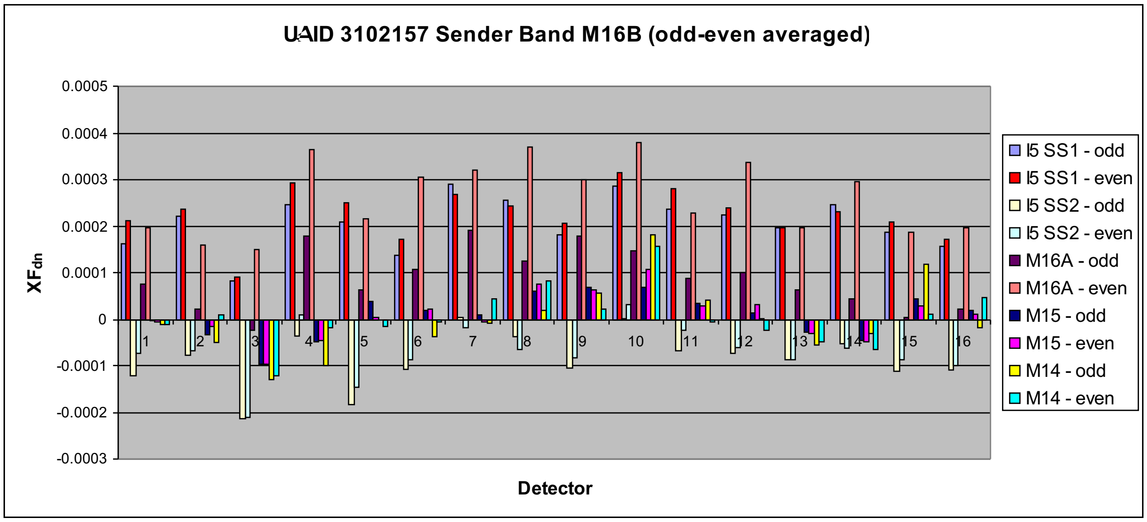
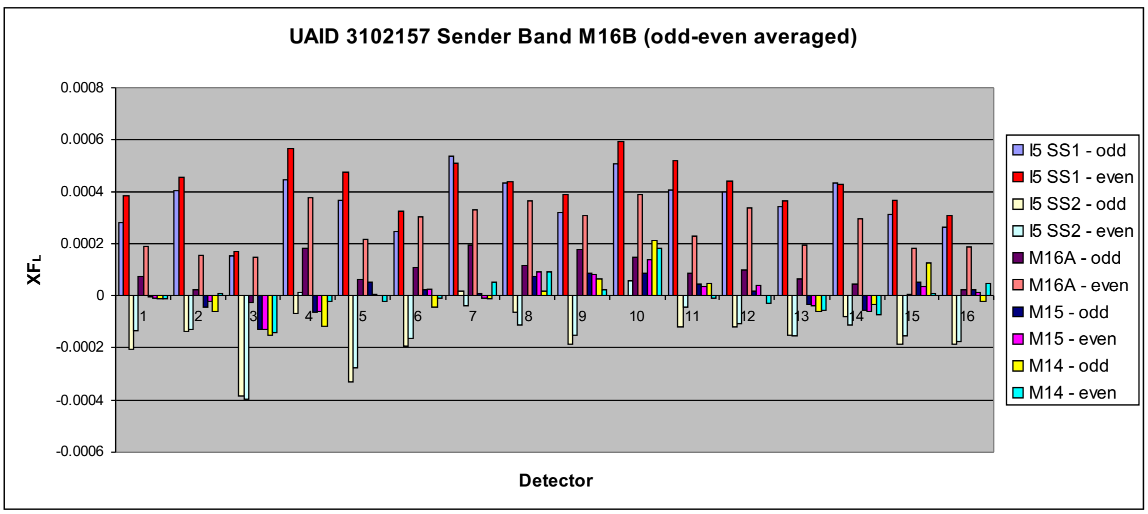


Figure 2: FU1 FP-13 odd-even averaged crosstalk coefficients in dn, radiance, and noise space for sender band M16B





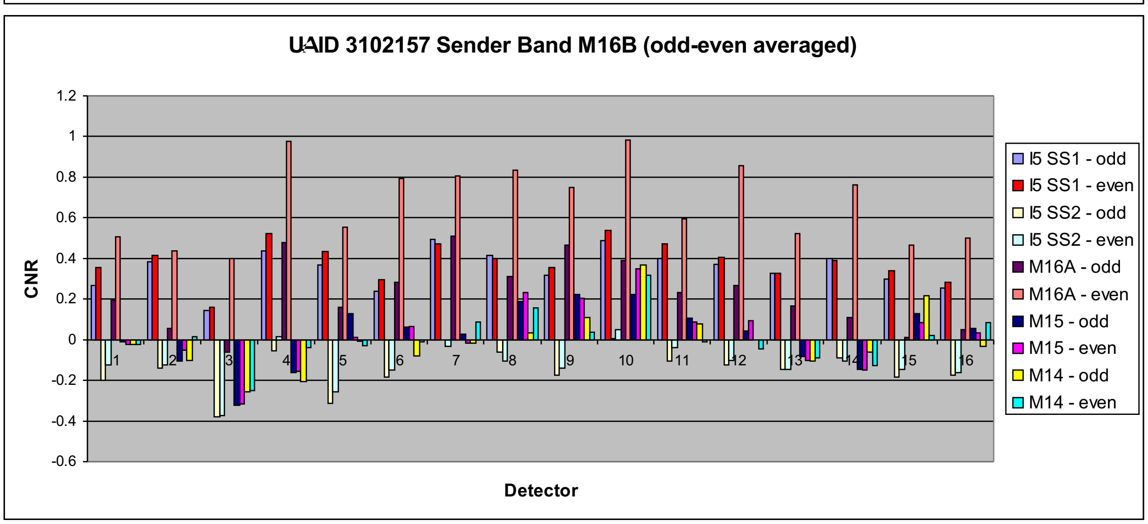


Figure 3: FU1 FP-13 XF_{dn} for sender band M16B, detectors 1 - 16, respectively

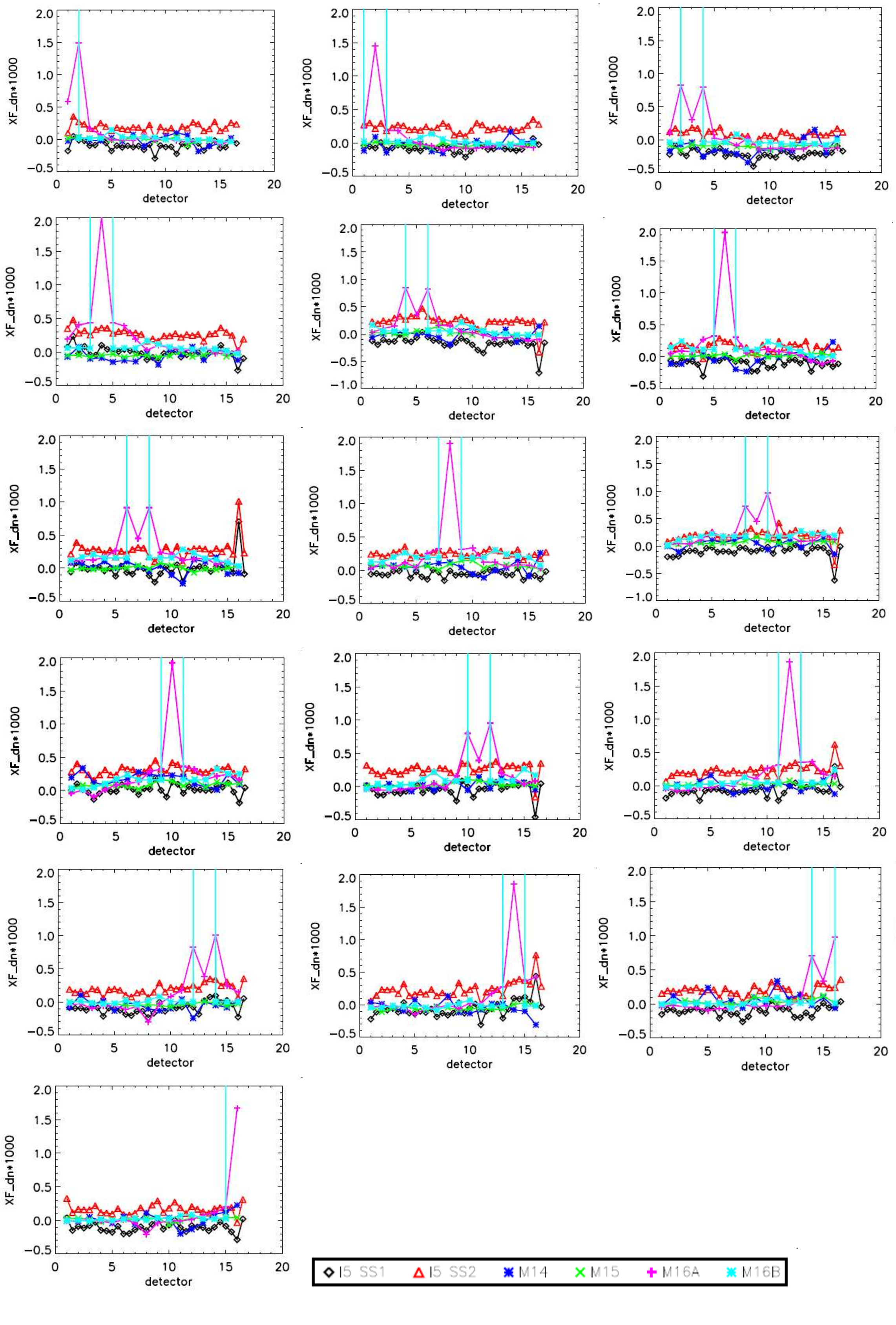
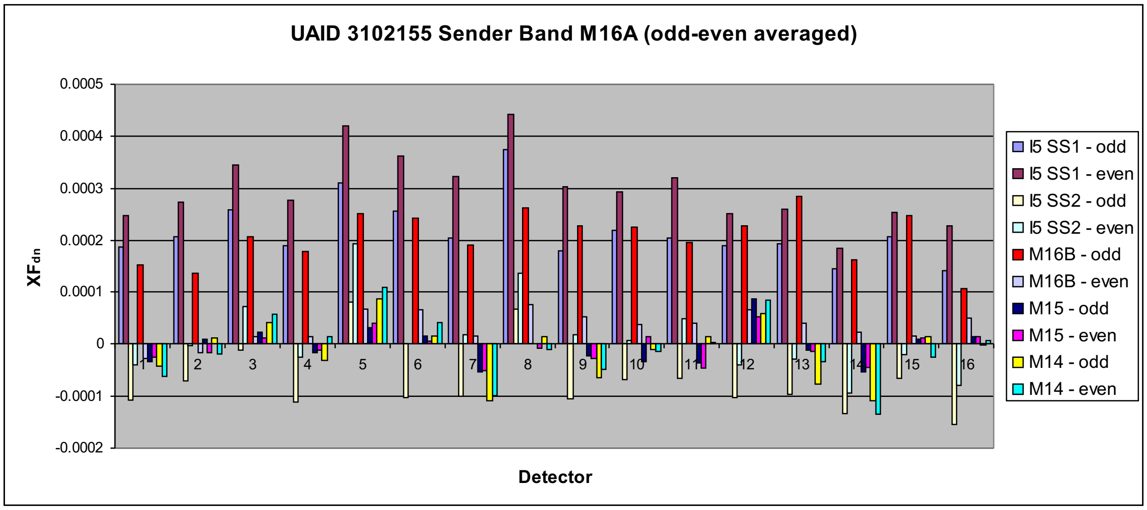
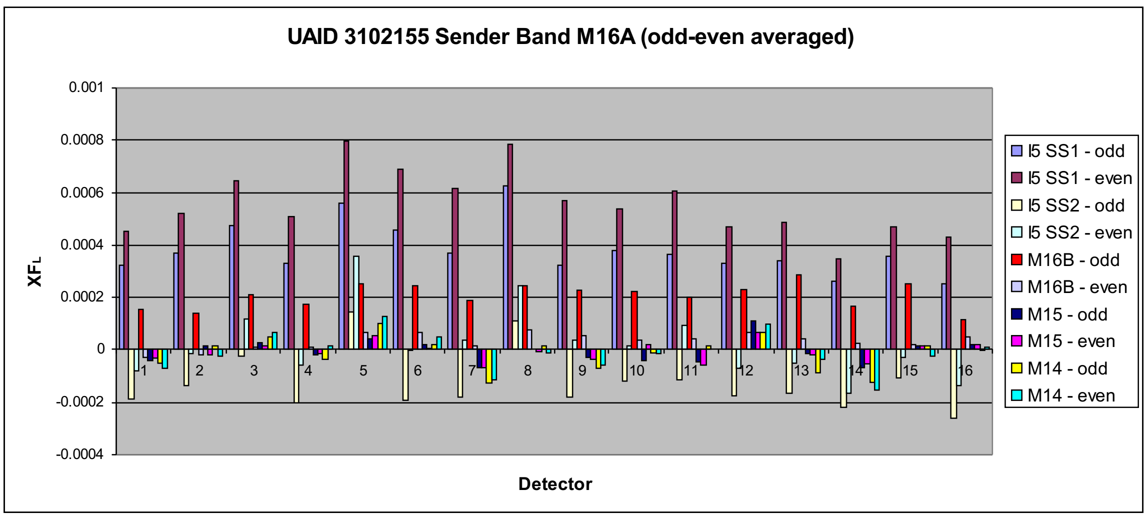


Figure 4: FU1 FP-13 odd-even averaged crosstalk coefficients in dn, radiance, and noise space for sender band M16A





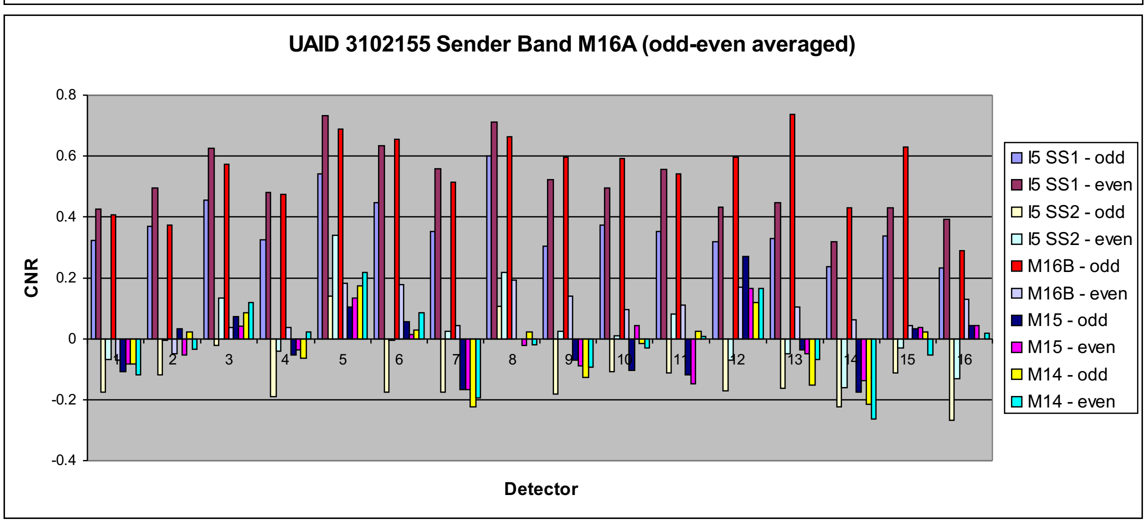


Figure 5: FU1 FP-13 XF_{dn} for sender band M16A, detectors 1 - 16, respectively

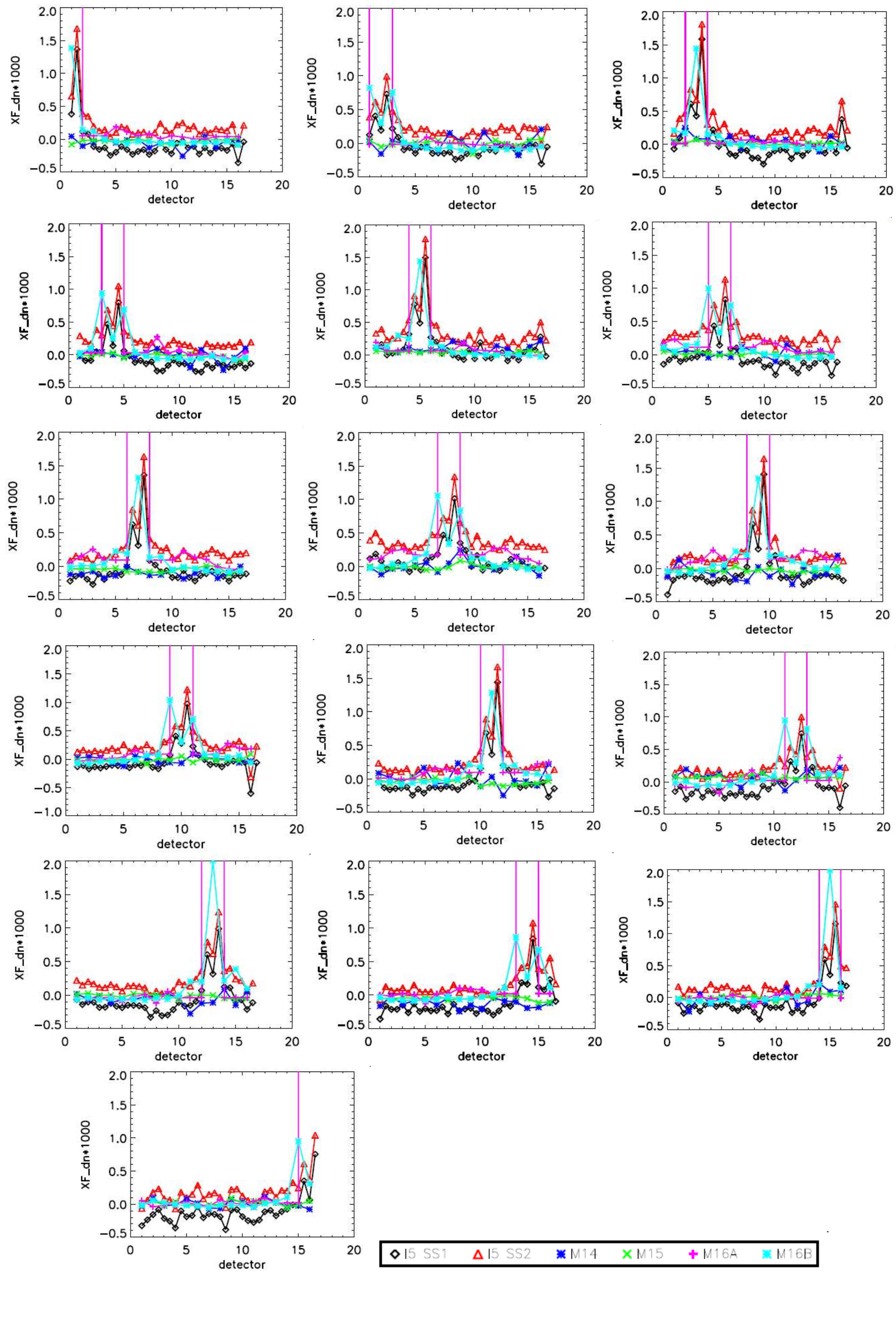


Figure 6: FU1 FP-13 odd-even averaged crosstalk coefficients in dn, radiance, and noise space for sender band I5

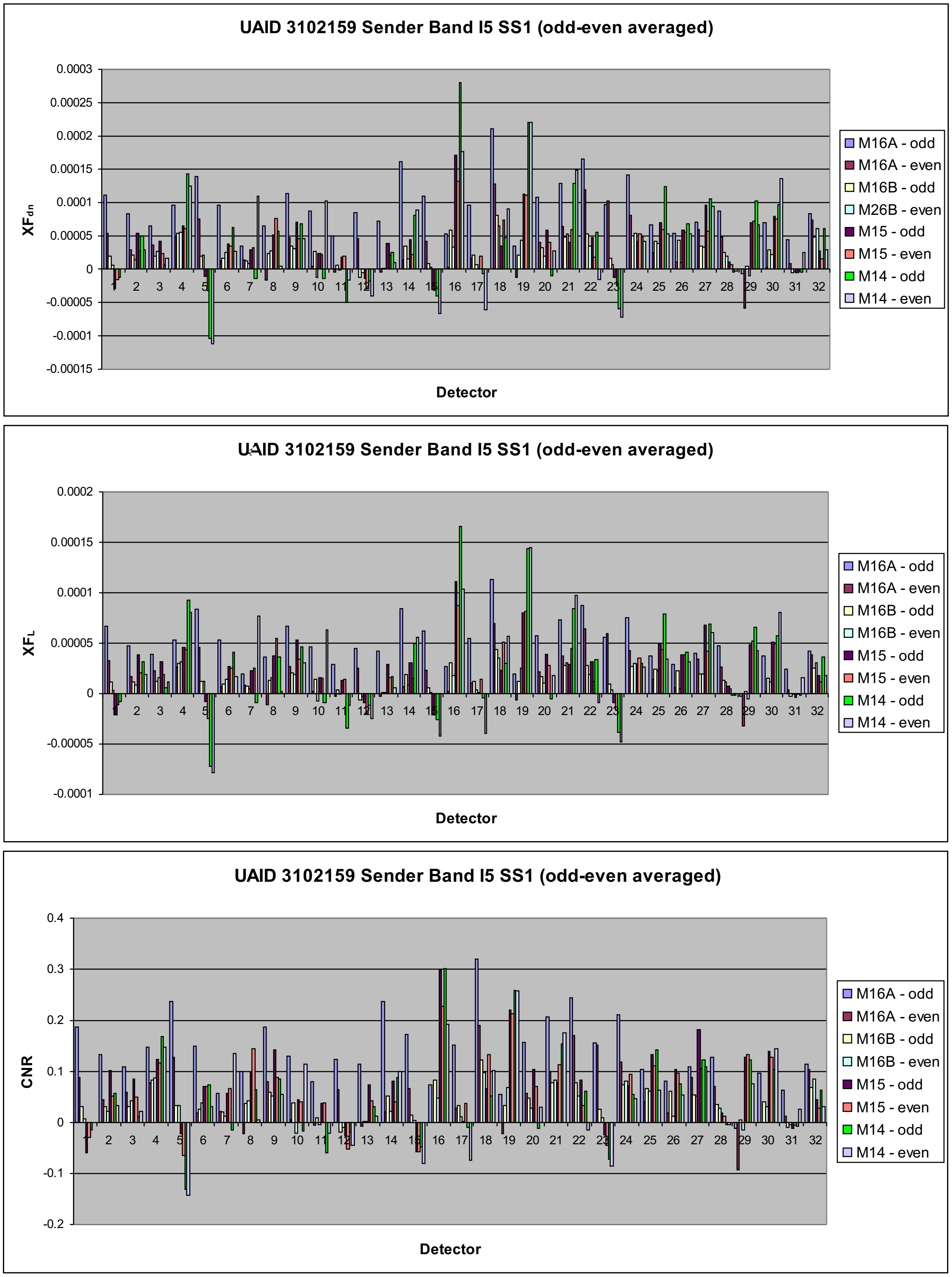


Figure 7: FU1 FP-13 XF_{dn} for sender band I5, detectors 1 - 16, respectively

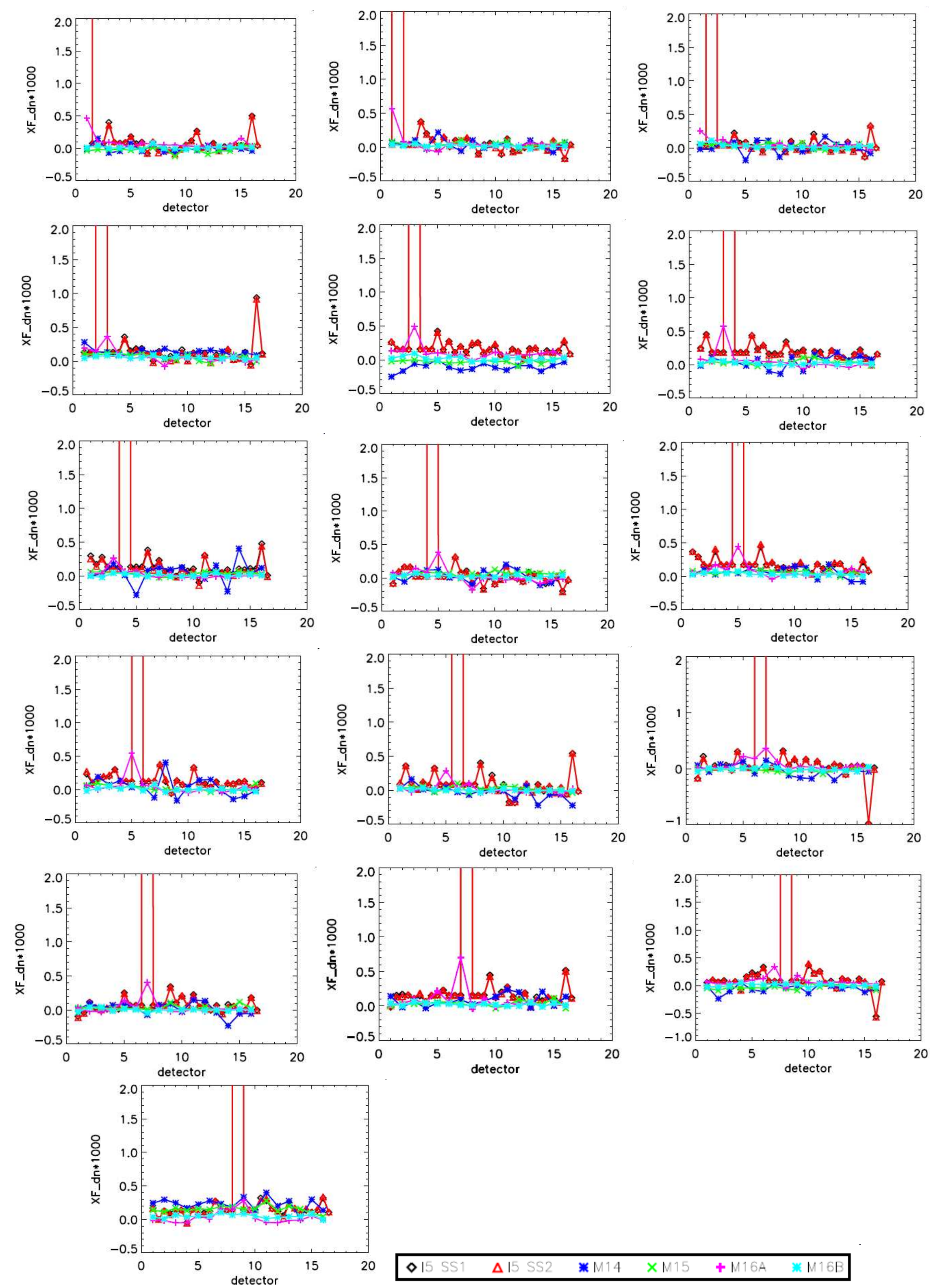


Figure 8: FU1 FP-13 XF_{dn} for sender band I5, detectors 17 - 32, respectively

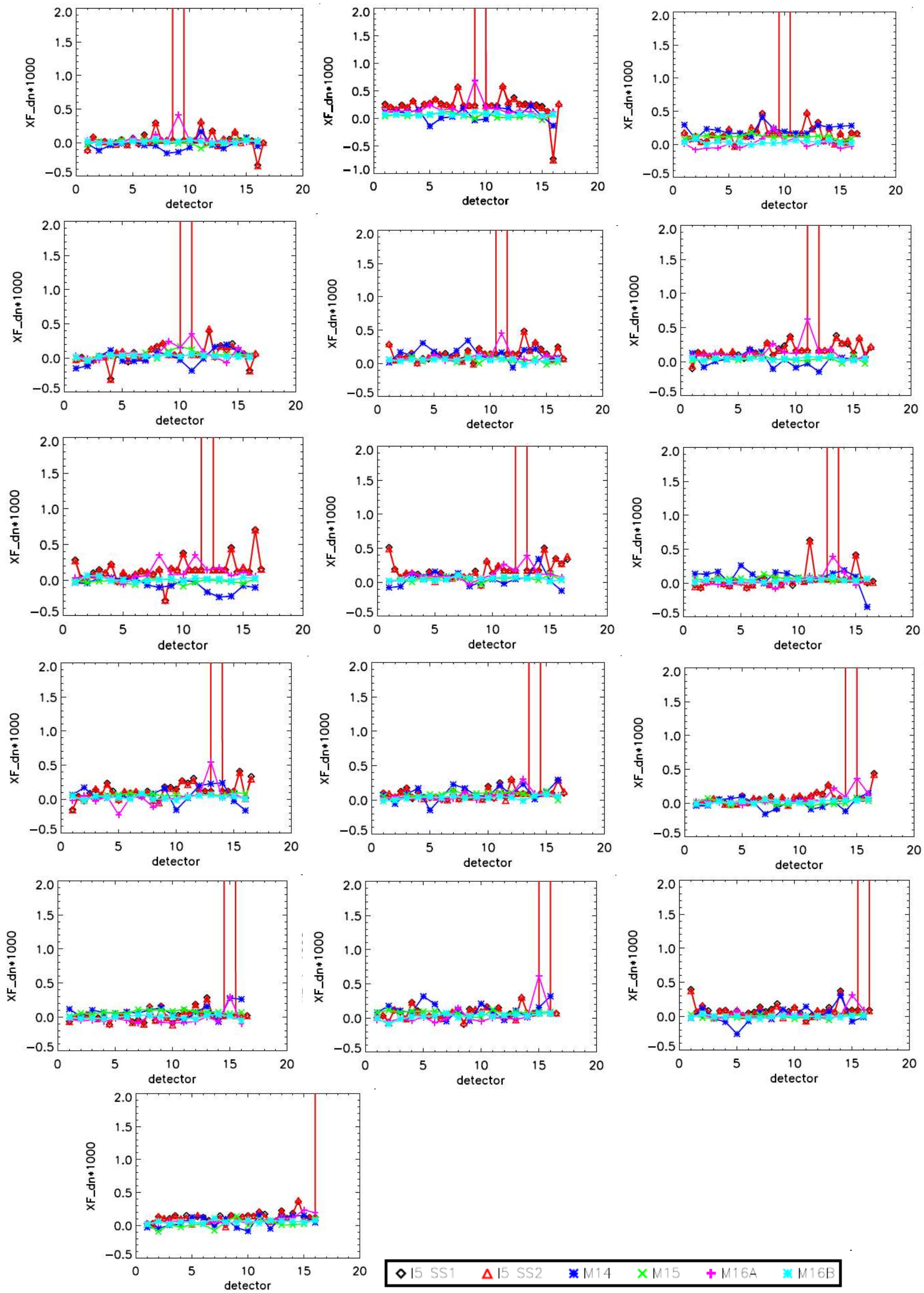
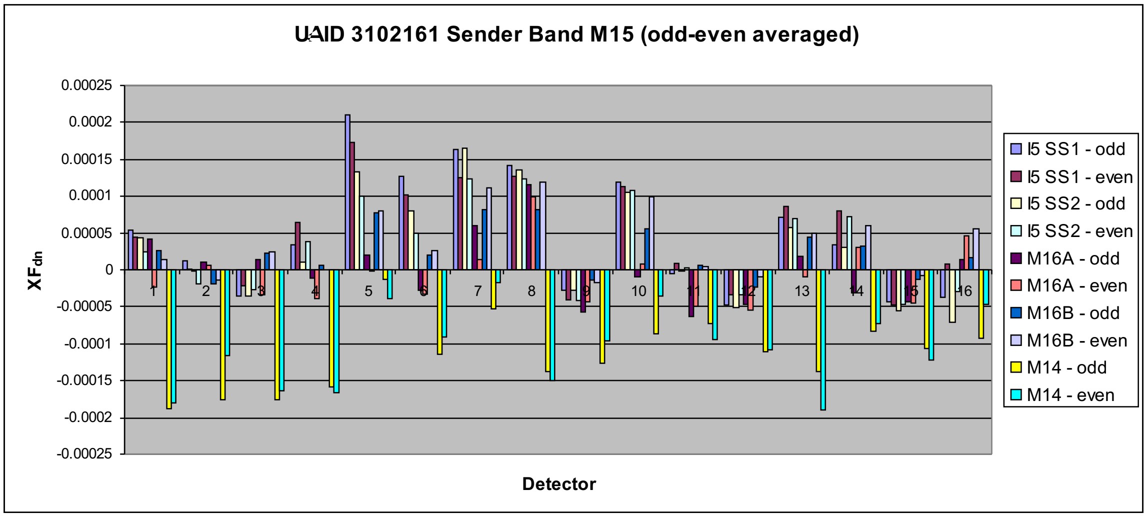
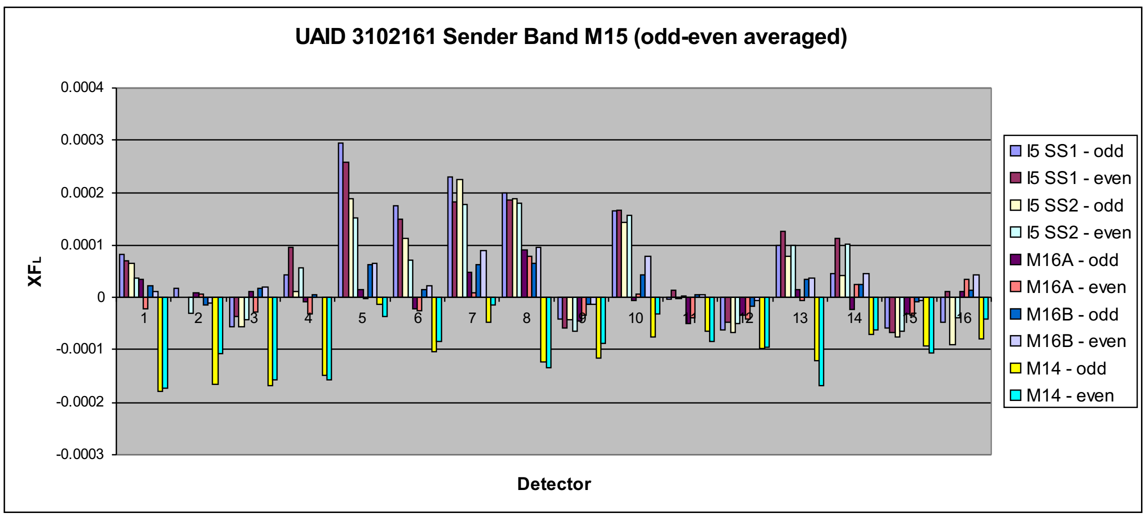


Figure 9: FU1 FP-13 odd-even averaged crosstalk coefficients in dn, radiance, and noise space for sender band M15





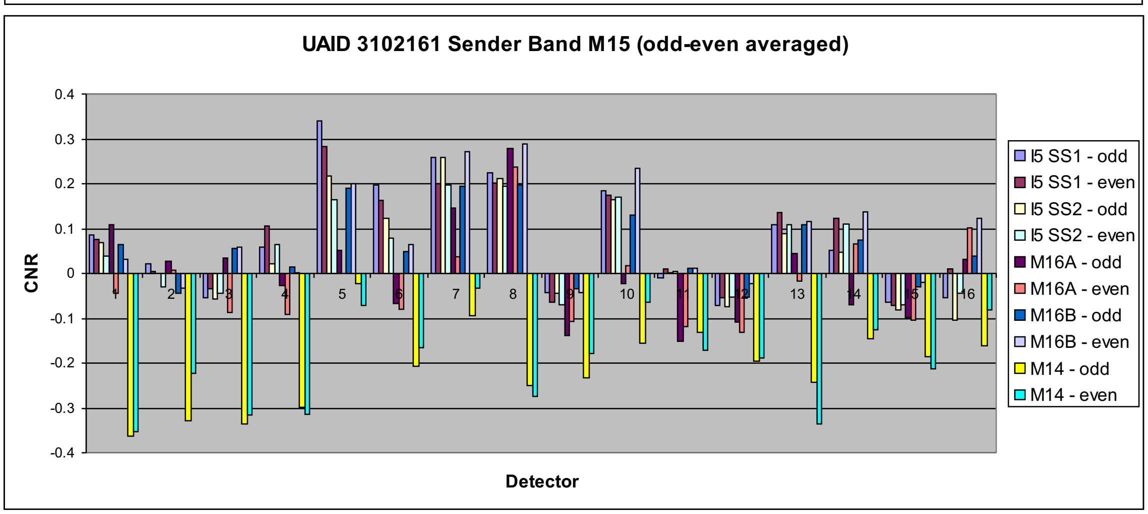


Figure 10: FU1 FP-13 XF_{dn} for sender band M15, detectors 1 - 16, respectively

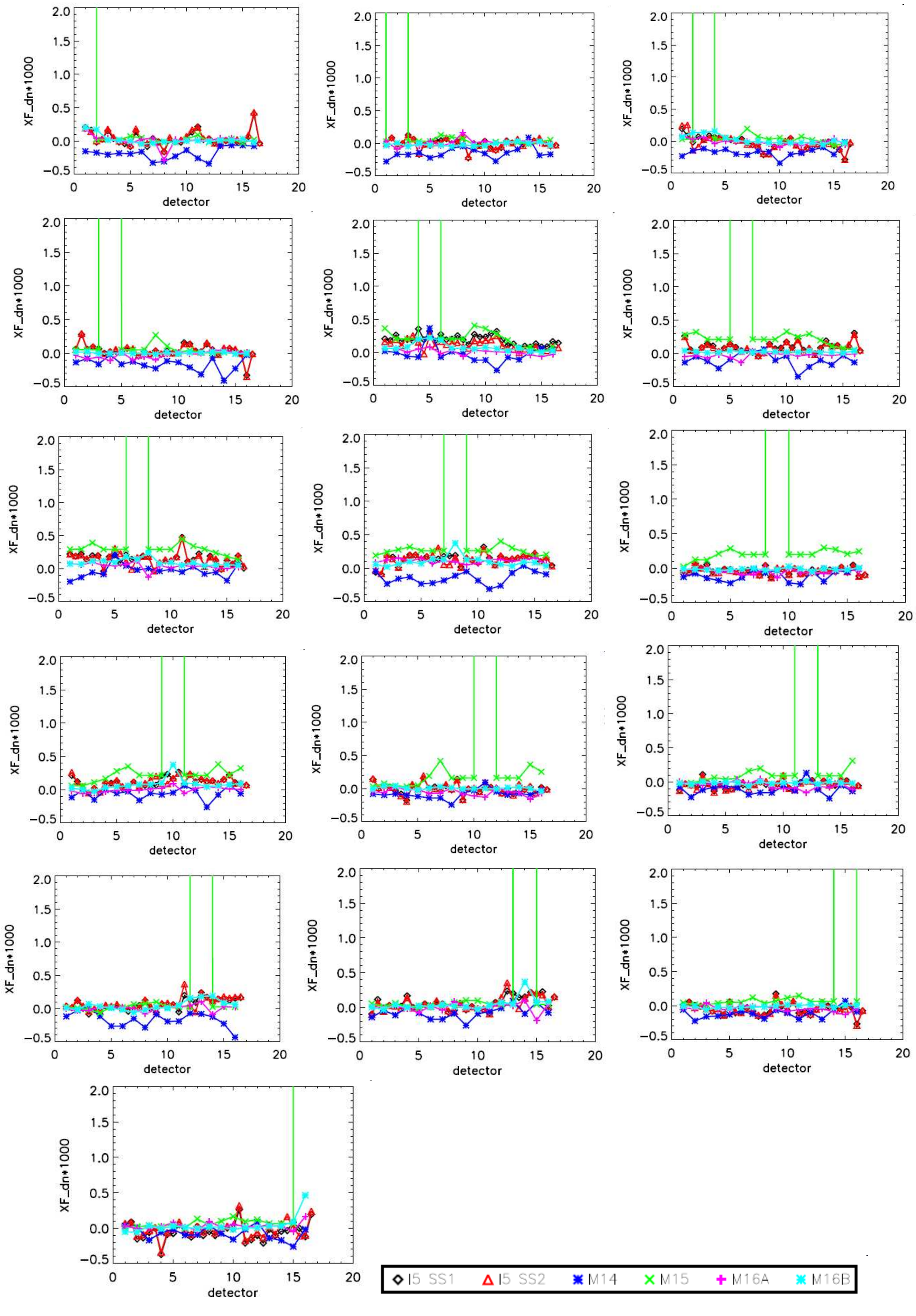
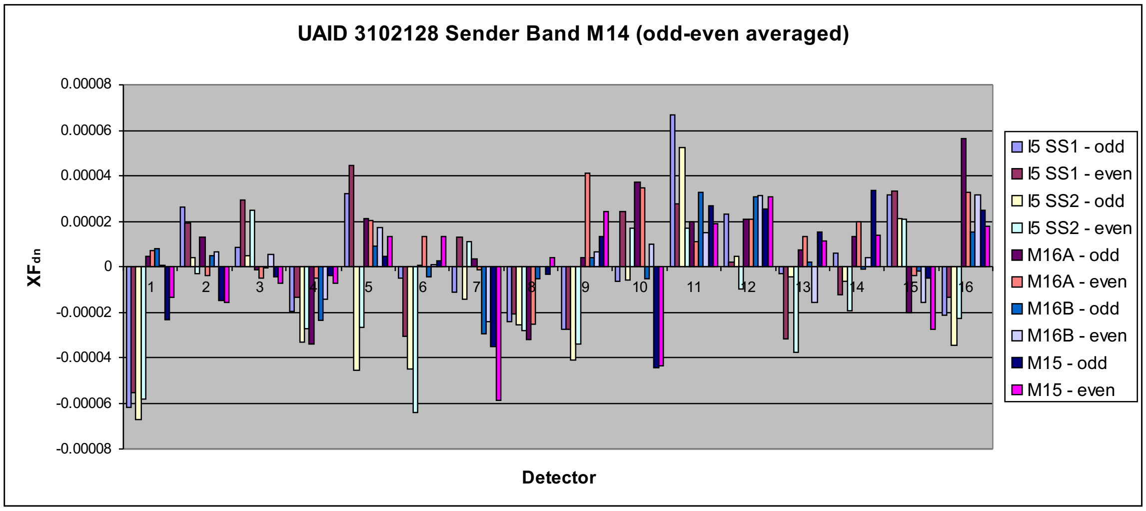
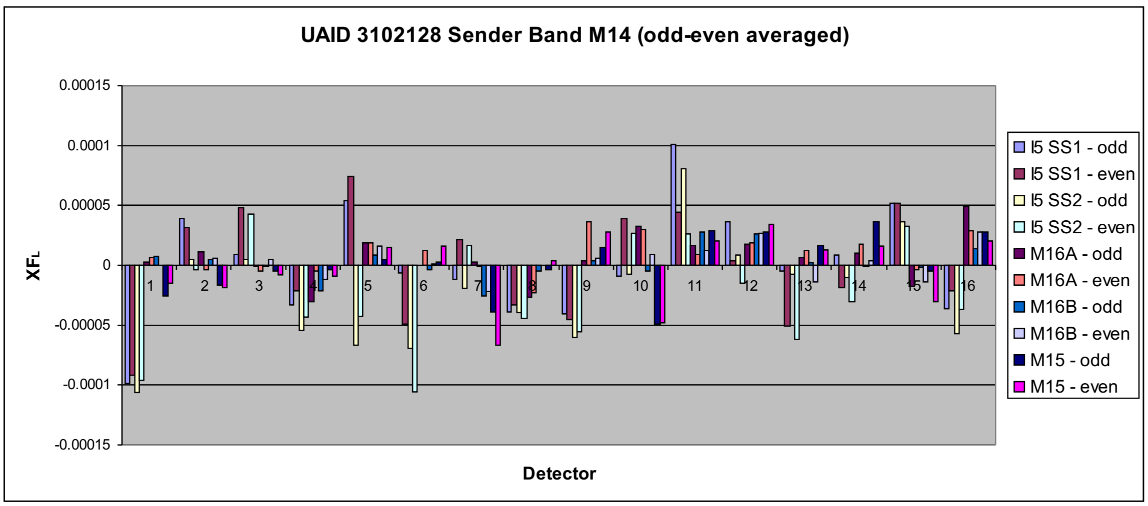


Figure 11: FU1 FP-13 odd-even averaged crosstalk coefficients in dn, radiance, and noise space for sender band M14





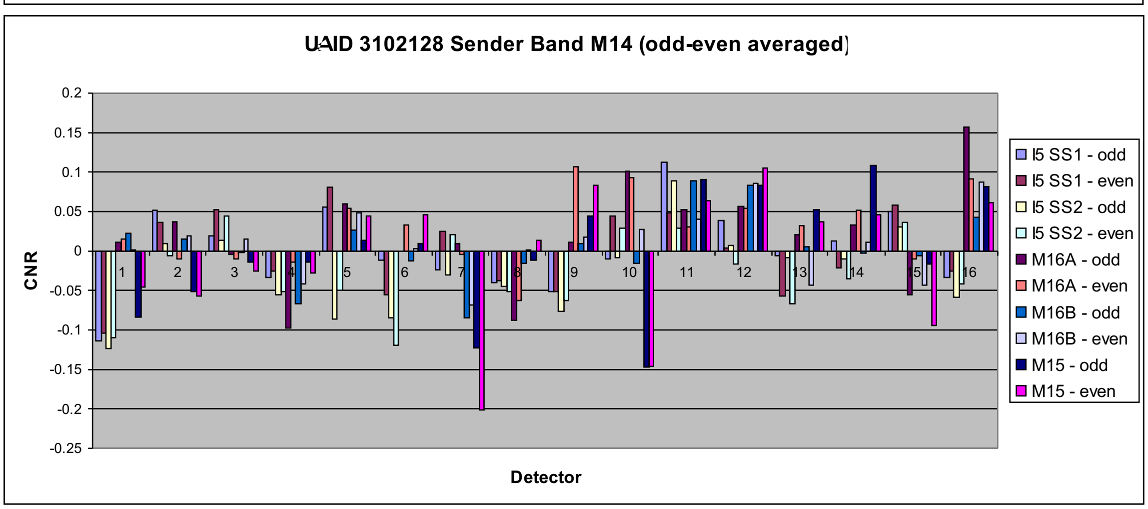


Figure 12: FU1 FP-13 XF_{dn} for sender band M14, detectors 1 - 16, respectively

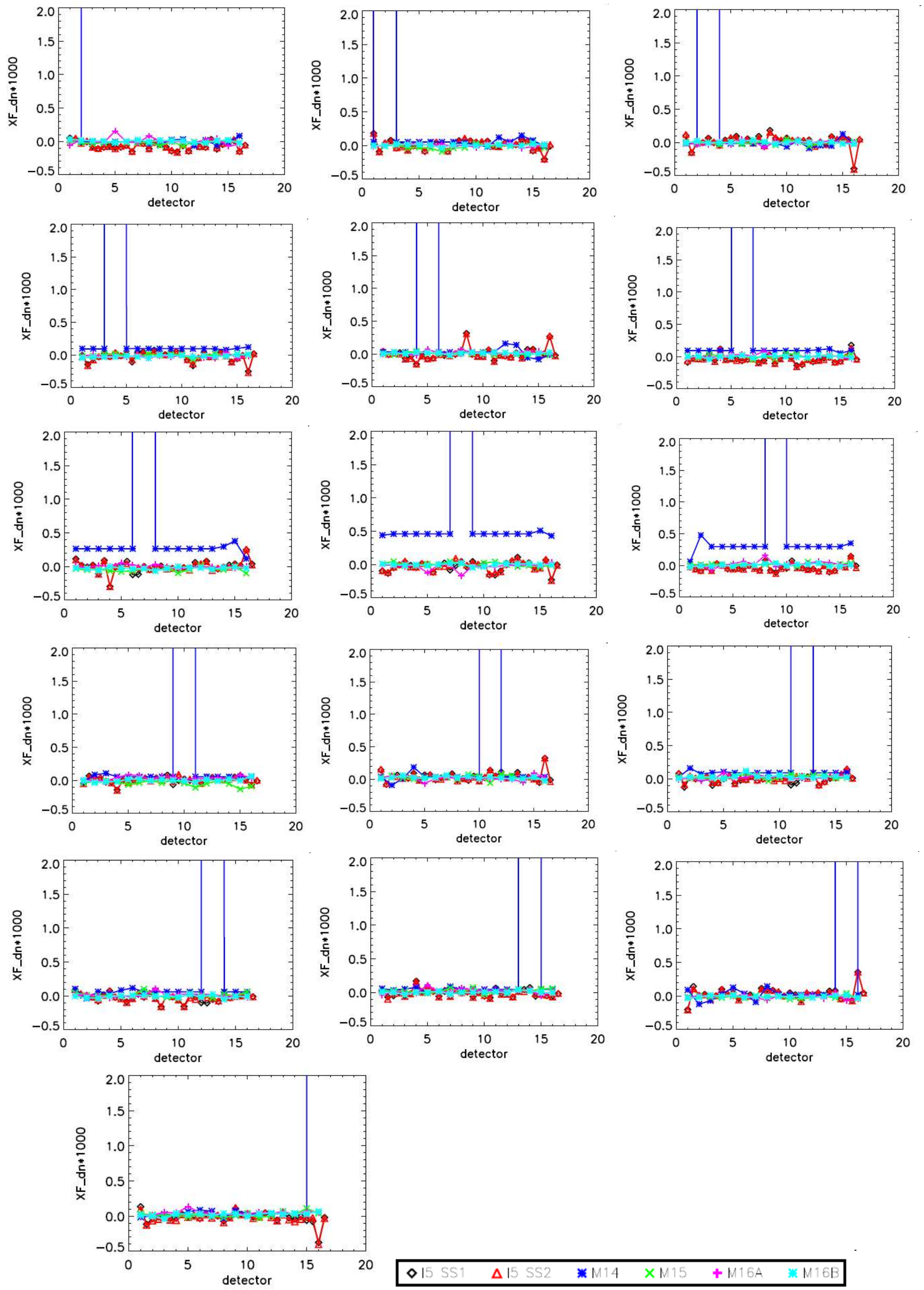


Figure 13: FU1 FP-13 CNR and PVP_{Spec} for sender band M15, detectors 1, 4, 5, 10, and 14, respectively

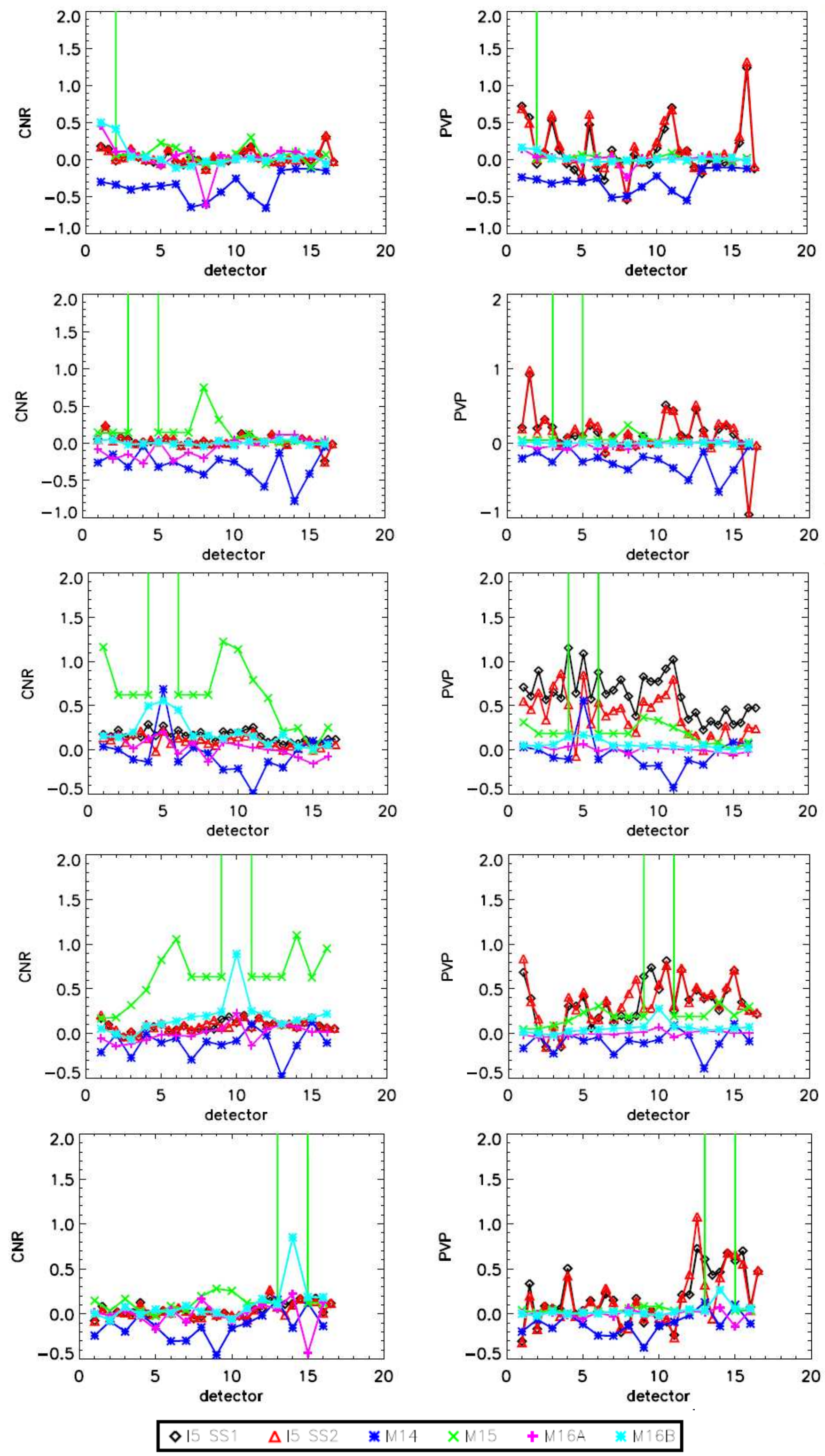


Figure 14: FU1 FP-13 CNR and PVP_{Spec} for sender band M16B, detectors 1, 4, 6, 11, and 15, respectively

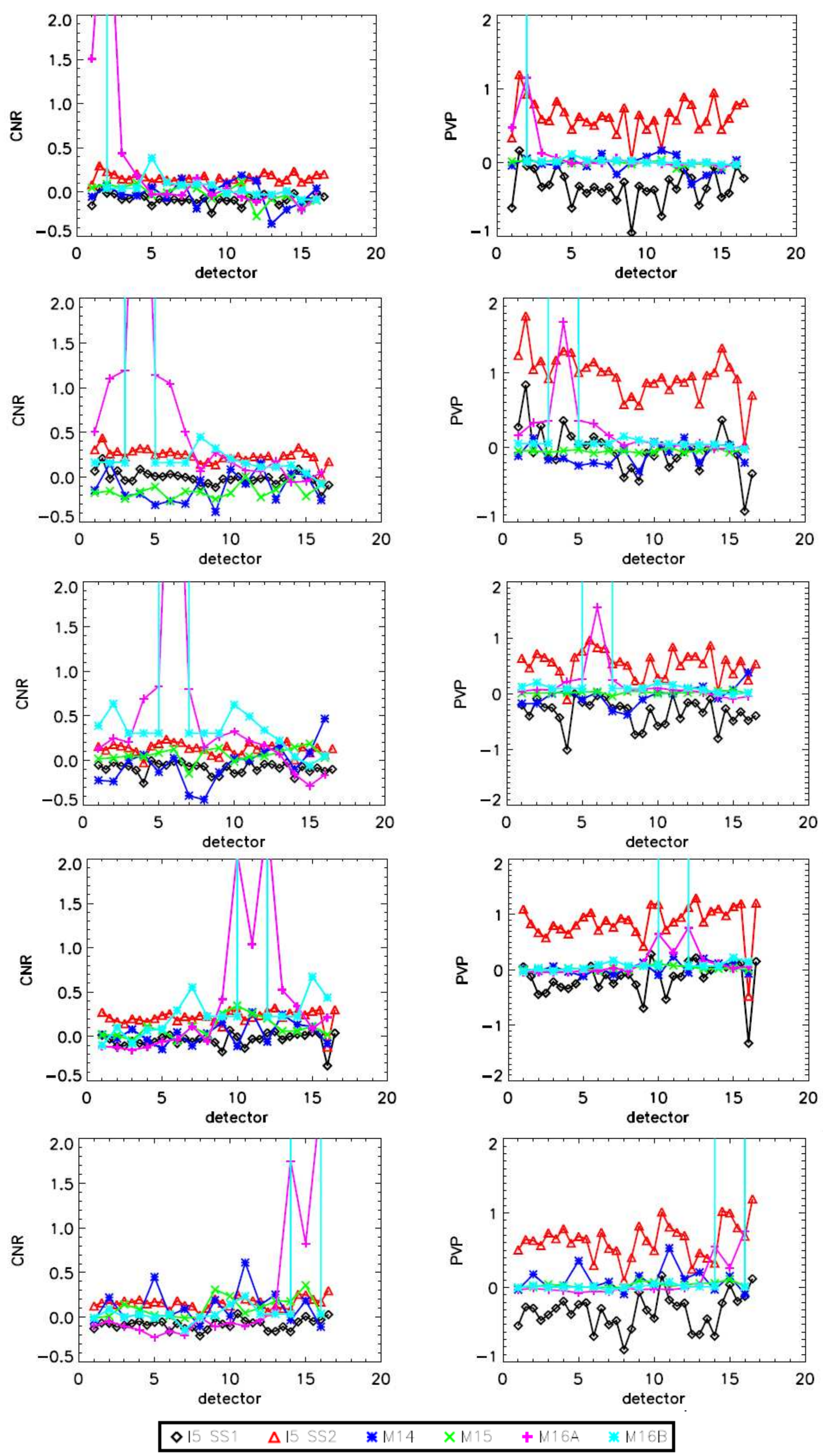


Figure 15: FU1 FP-13 OOB response in M16B from sender band M15, detectors 8, 10, 14, and 16, respectively

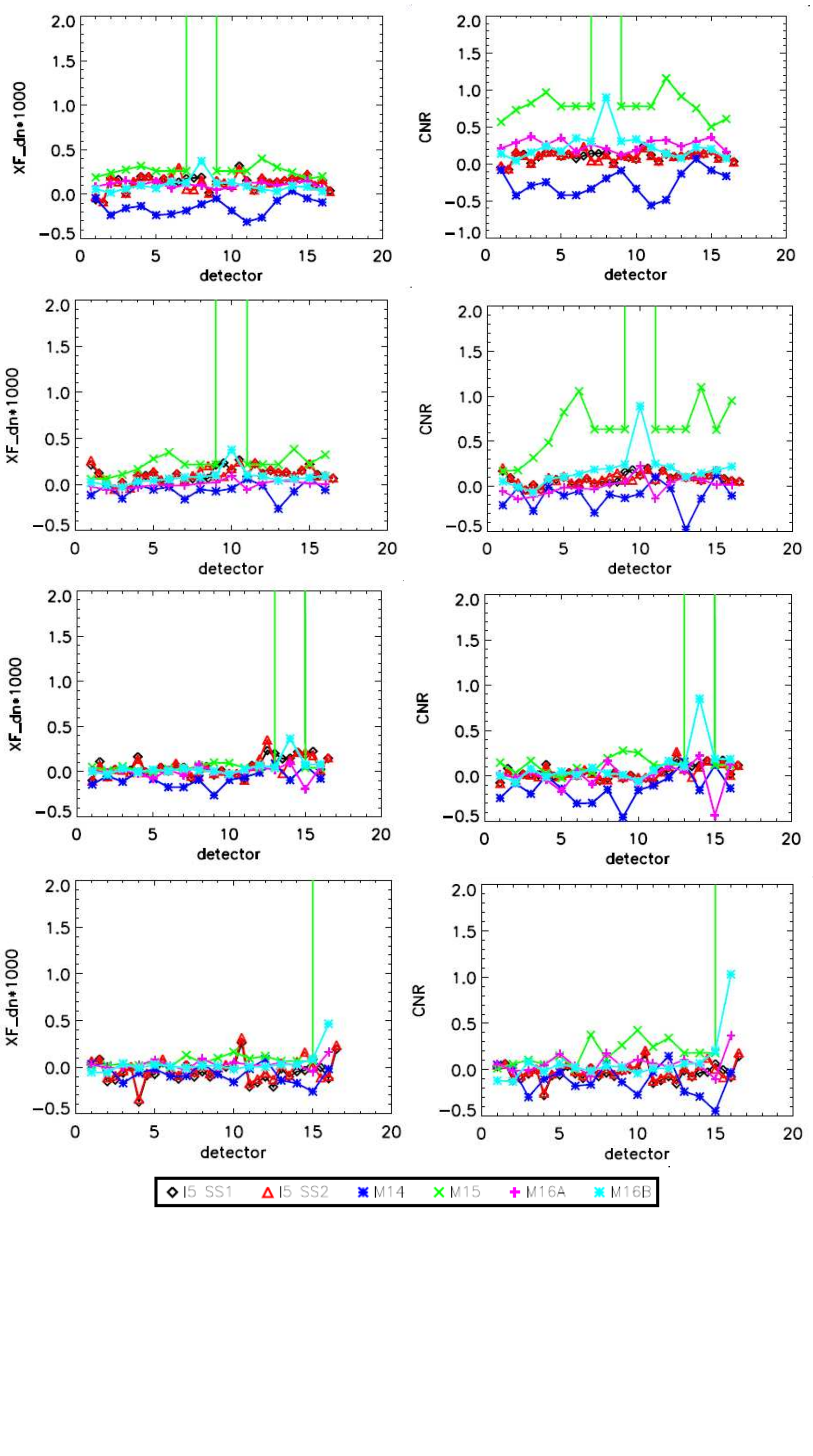


Figure 16: FU1 FP-13 CNR for sender band M13 ahg, detectors 4, 7, 8, 11, 13, and 16, respectively

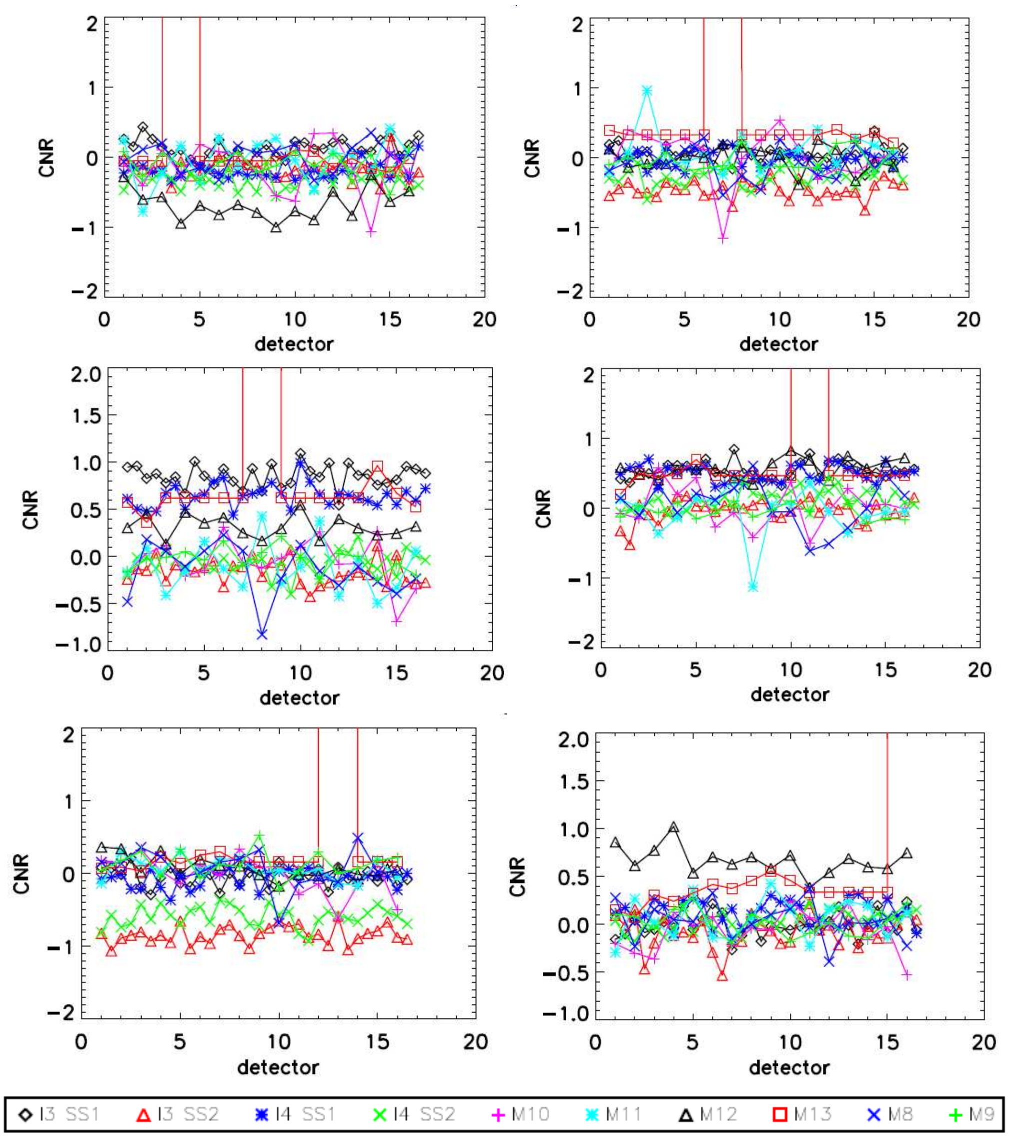


Figure 17: FU1 FP-13 CNR and PVP_{Spec} for sender band M12, detectors 4, 5, 8, 11 and 14, respectively

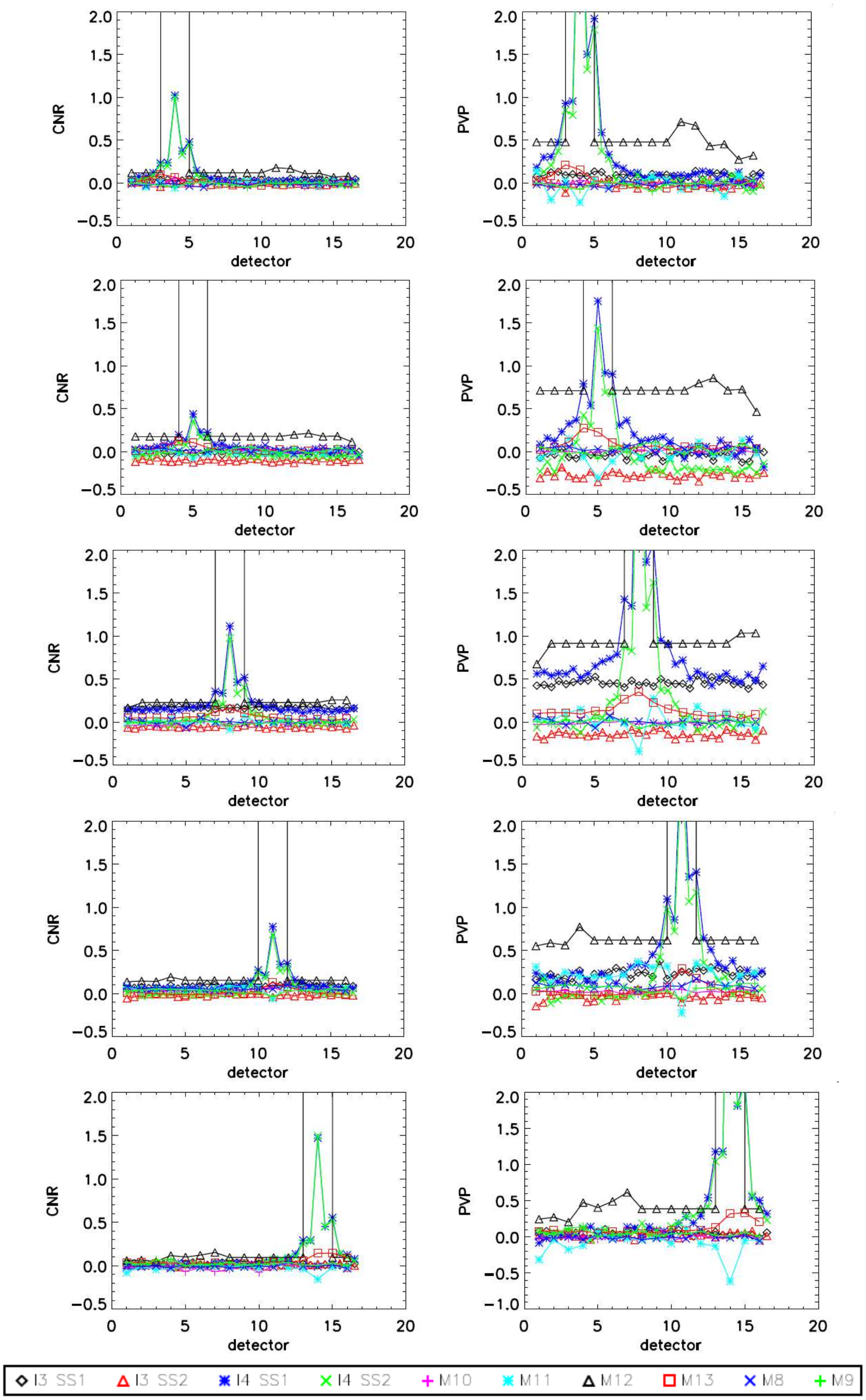


Figure 18: FU1 FP-13 CNR and PVP_{Spec} for sender band M9, detectors 2, 5, 8, 13, and 15, respectively

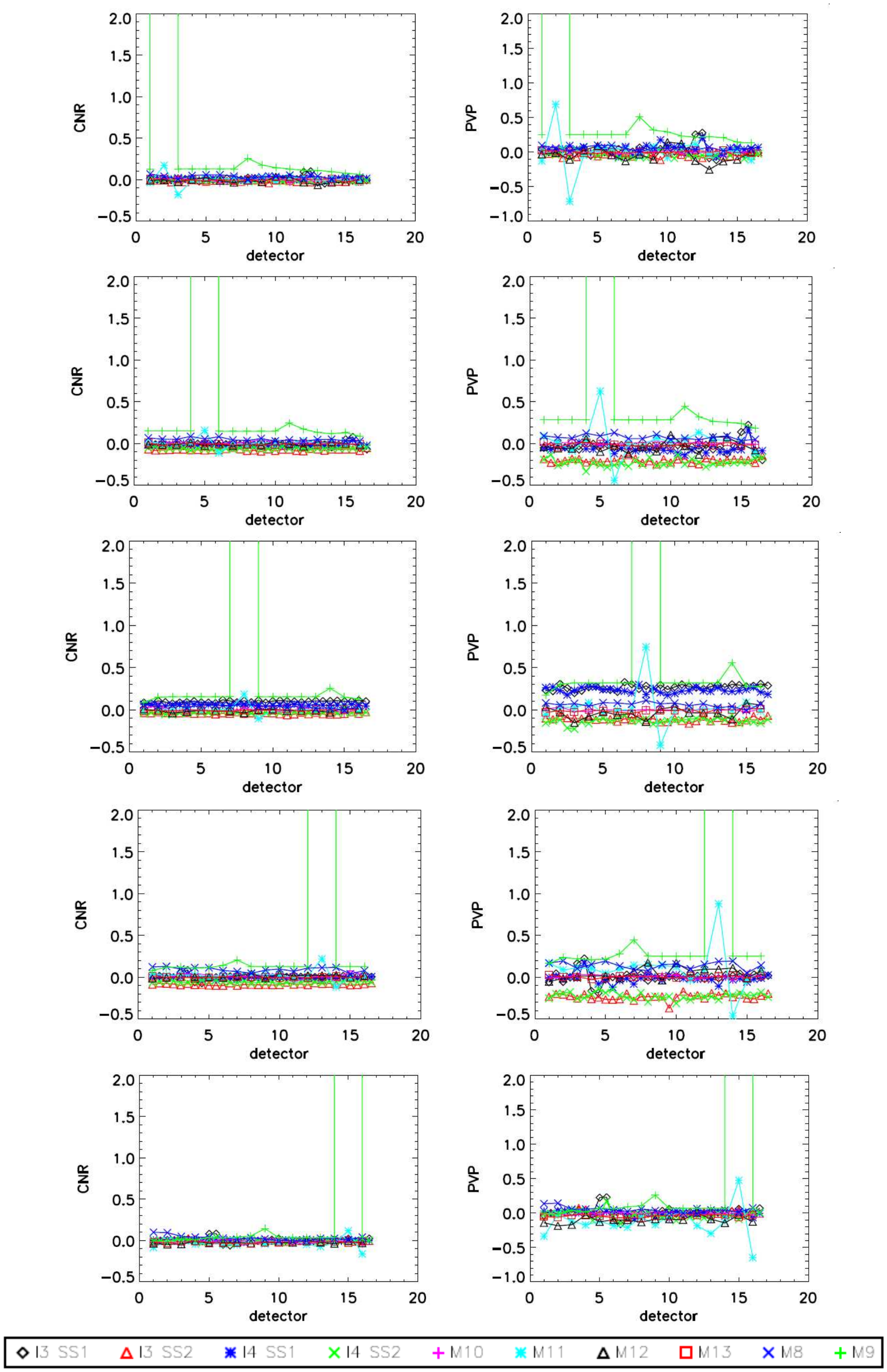


Figure 19: Comparison of shutter open and closed dn for BPF M14 and reticle over detector 1. Also included is the dn from detector 8 for the same collect.