Symmetric and Near-Gaussian Pulses and the TWDP Stressor Set

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IEEE P802.3aq 10GBASE-LRM Task Force

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Discovering Beyond Imagination

Outline

1. Summary – need to include symmetric stressor with PIE-D (=PIE(12,5)) approximately 4.4dB, corresponding to offset BW of approximately 660MHz.km
2. Analytical Procedure – diagnostic plots emphasize that OM1 20um offset launch typically generates a symmetric pulse. Focus on 220m, 20um offset, EMB vs PIE-D
3. Discussion & Recommendation

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4. Backup Analysis – plots of EMB vs PIE(12,5), FWQM, "energy outside bit window" support recommendation. Plots at 300m included for reference. Plots for 4um, 5um included for reference.

Summary

Diagnostic plots of -3dB Effective Modal Bandwidth (EMB) vs. PIE-D were made for the 20um offset launch, and the 75 Ewen stressor candidates.

The plots show that at 220m and a PIE-D EDC capability of 4dB, the offset BW be > 700-750MHz.km for success. The stressor candidates have a lower PIE-D (i.e. are easier to equalize) than typical fibers with the same offset BW.

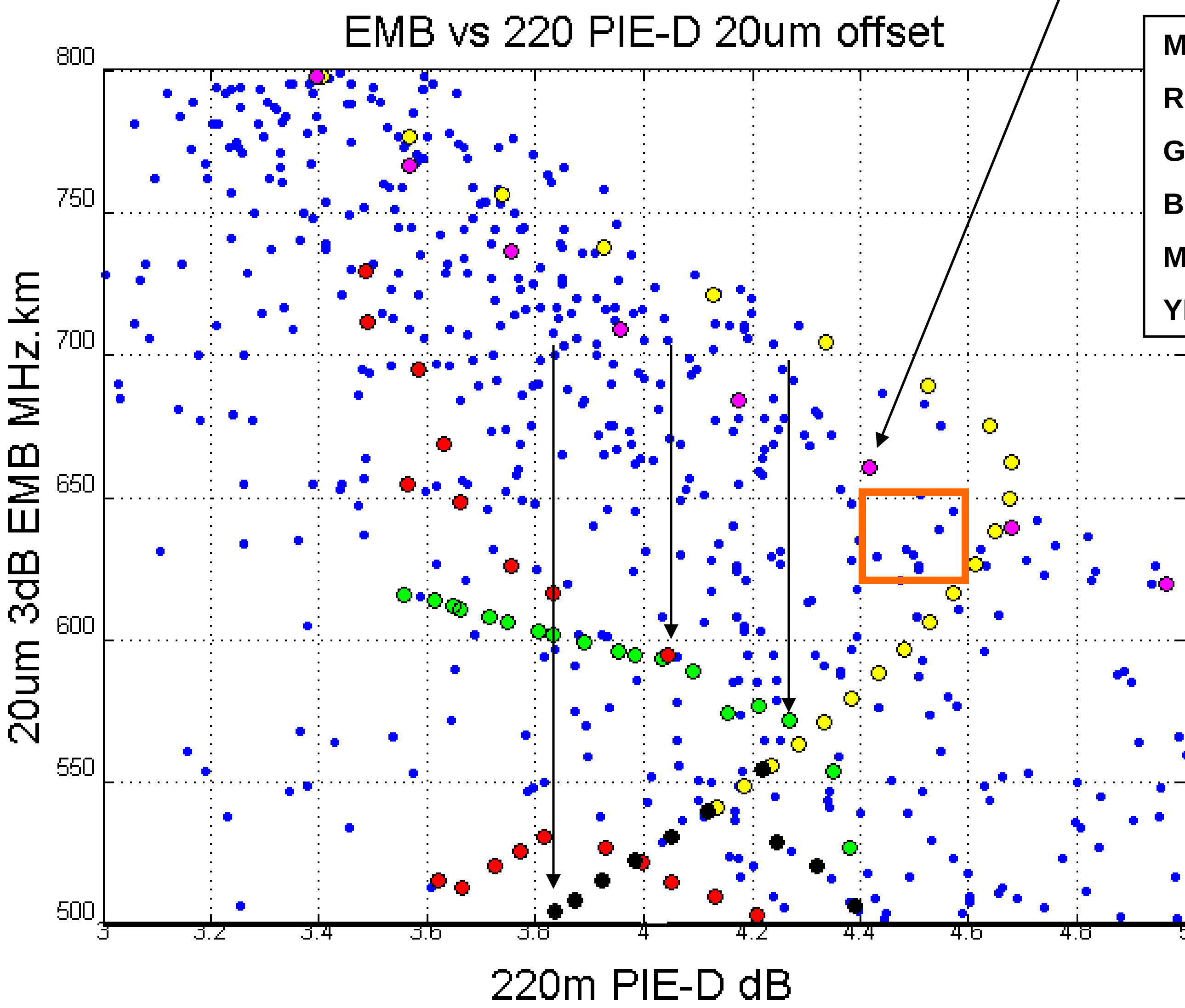
Proposed Additional Stressor

The plot of EMB vs PIE-D for the standard 20um offset launch for OM1 fiber suggests that an additional category of impulse response should be included: **near-symmetrical pulses, which for a given EMB have the worst PIE-D values**. The edge of the EMB vs. PIE-D distribution is marked by these fibers.

The limit of PIE-D = 4.0dB at 220m is reached by an example symmetric stressor with an EMB of 709 MHz.km (at 300m, EMB = 967MHz.km).

The PIE-D and finite equalizer penalties capture the tradeoff between how much the eye needs to be opened and how difficult that is to achieve needs to be understood.

Proposed Additional Stressor



MC67YY OM1 data set.

RED: Ewen precursor set

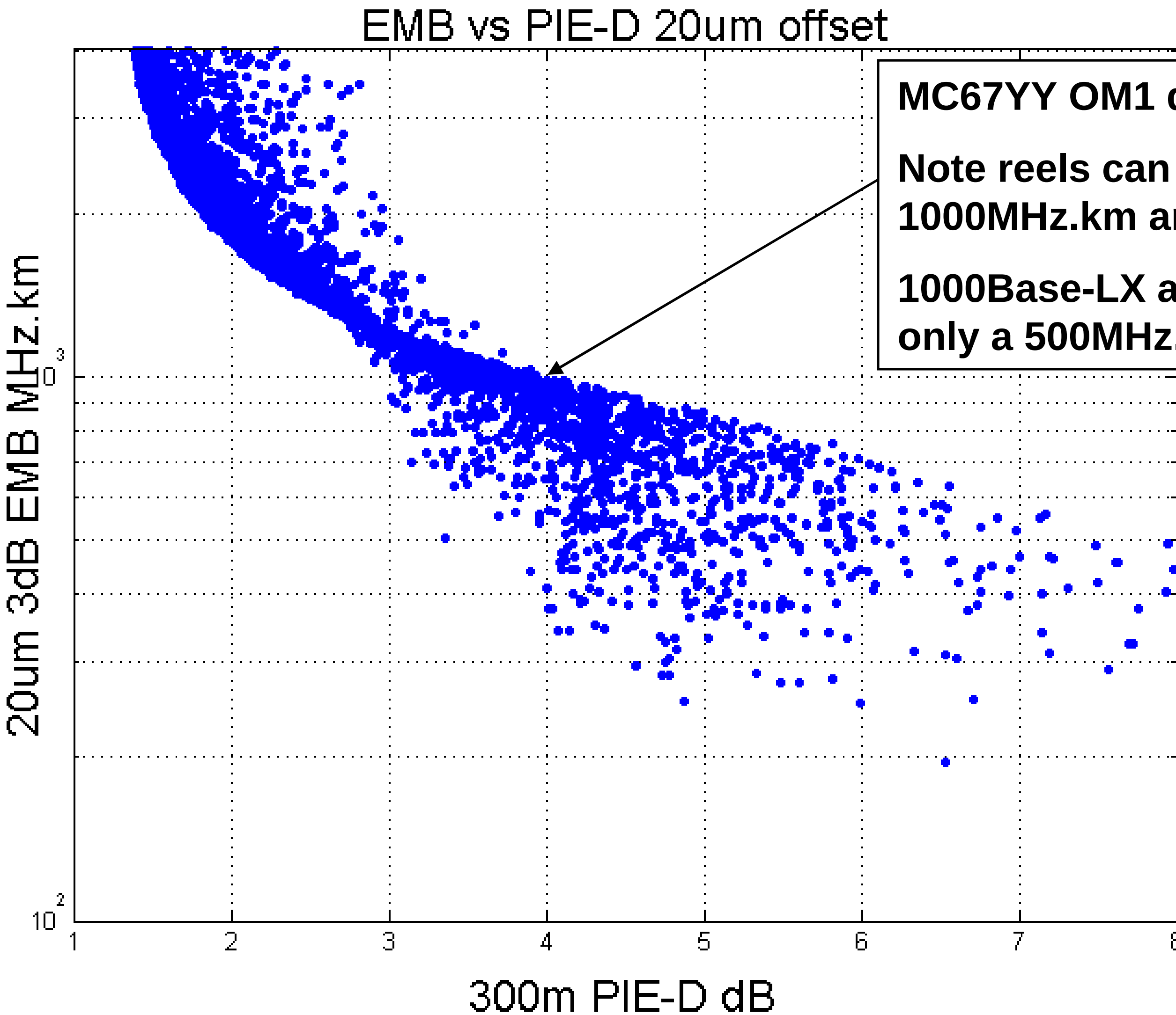
GREEN: Ewen postcursor set

BLACK: Ewen split sym set

MAGENTA: JSA symmetric set 1

YELLOW: JSA symmetric set 2, 2b

20um offset EMB vs. PIE-D (300m)



MC67YY OM1 data set.

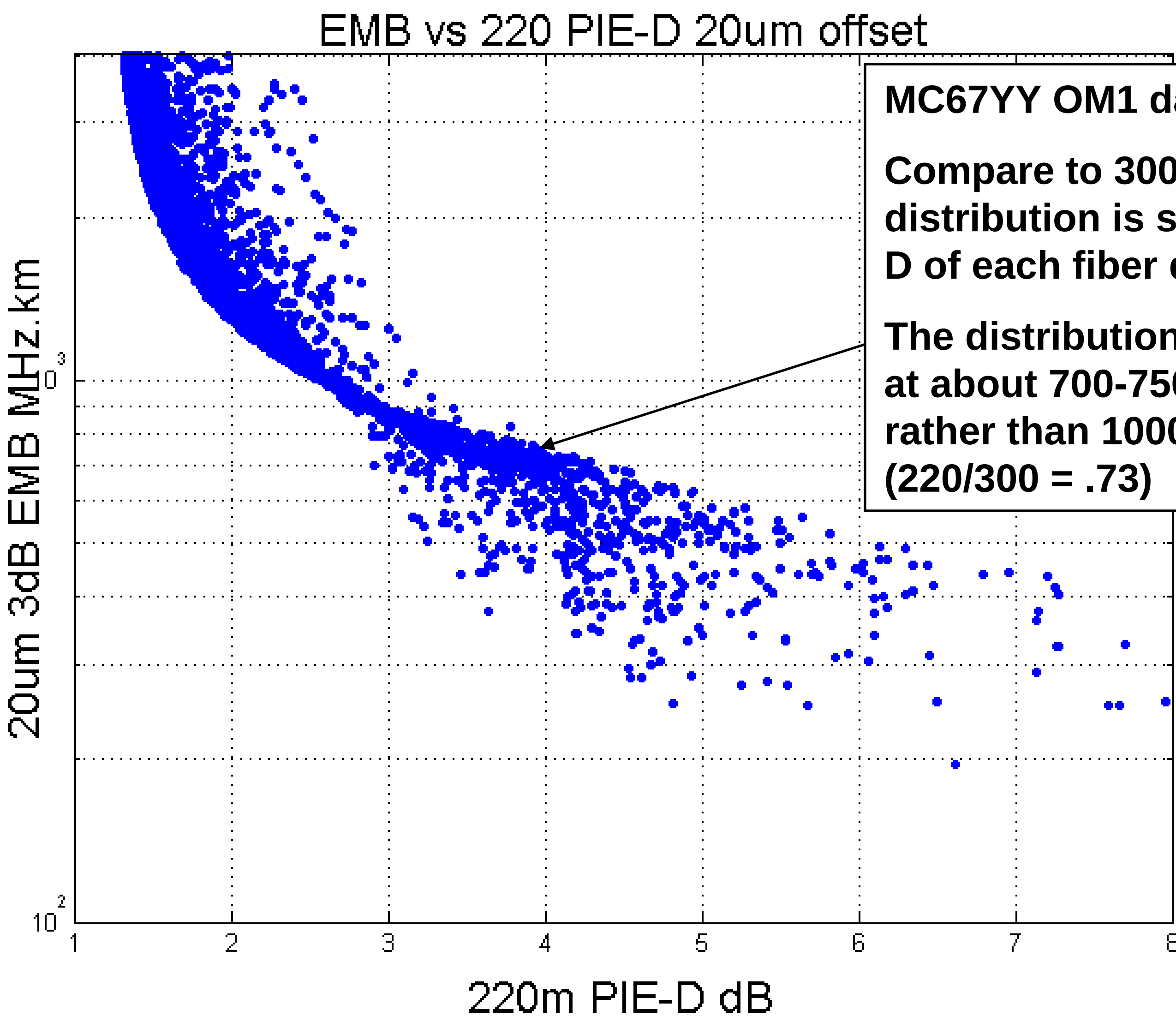
Note reels can have an EMB of almost 1000MHz.km and fail a 4dB PIE-D

1000Base-LX and GBASE LX-4 require only a 500MHz.km offset BW

A similar pattern shows up using PIE(12,5) instead of PIE-D

or FWQM or "energy outside bit window" for EMB.

20um offset EMB vs. PIE-D (220m)

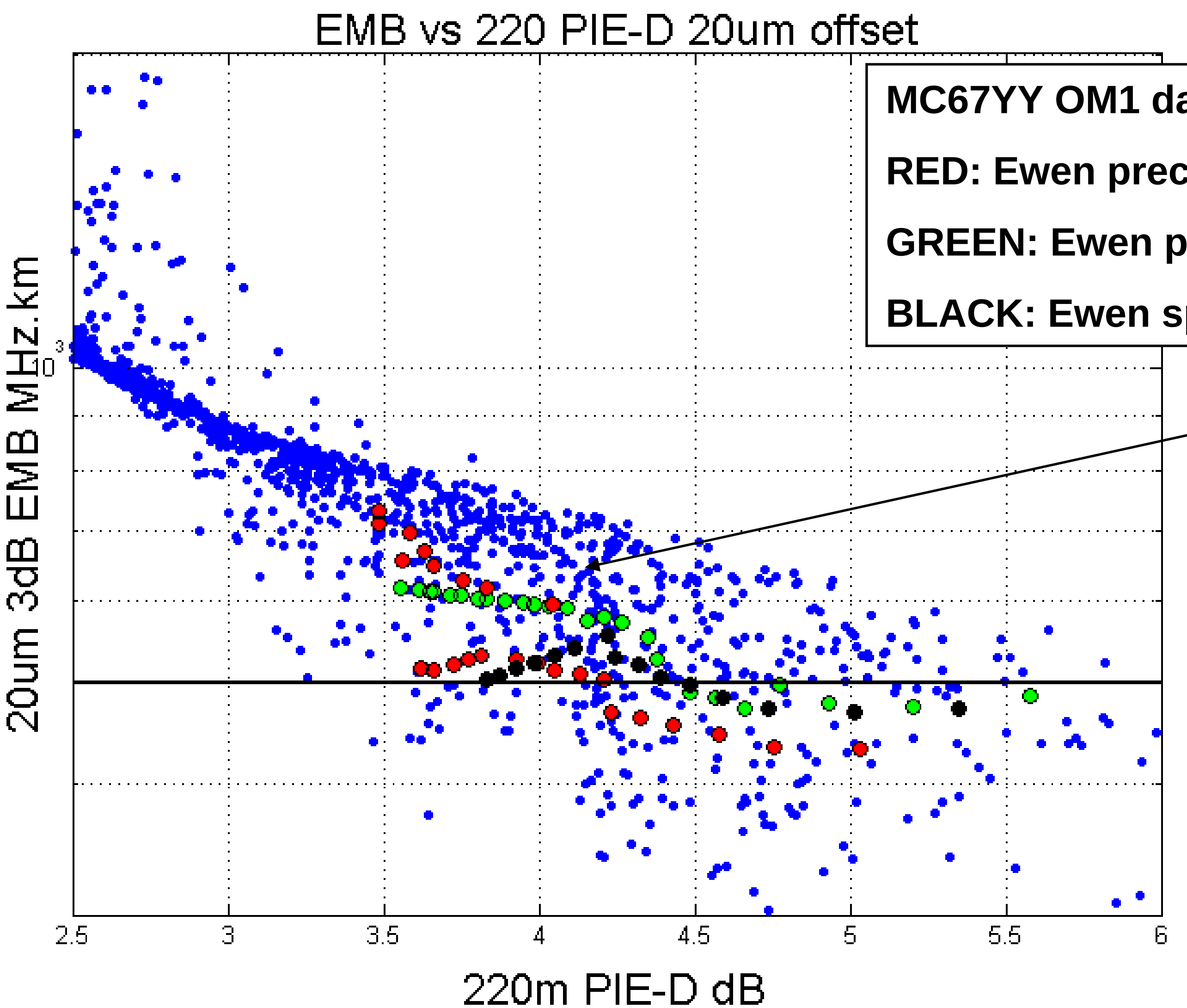


MC67YY OM1 data set.

Compare to 300m case – Same EMB distribution is shifted to the left as PIE-D of each fiber decreases.

The distribution crosses the 4dB level at about 700-750MHz.km for 220m rather than 1000MHz.km for 300m (220/300 = .73)

20um offset EMB vs. PIE-D (220m)



MC67YY OM1 data set.

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The 4dB stressor candidates have lower PIE-Ds than other fibers with same 20um offset BW: 3.8-4.0 stressor candidates are easier to equalize than most fibers with same offset BW.

New Stressors to Cover EMB-PIE-D space

The worst case PIE-D's for a given EMB are associated with a SYMMETRIC pulse which is not represented in the suggested stressor set.

It is not surprising that these are the toughest pulses, because a GAUSSIAN pulse is harder to equalize than a split pulse because there is less energy in the high frequency tail of the FFT.

We construct SYMMETRIC pulses within the Ewen 4-pulse framework by choosing A1=A4 and A2=A3. We start with A2=A3 = 0.5 and increase A1 by increments of 0.01. The implementation requires A1+A2+A3+A4=1.00, but this explains the construction.

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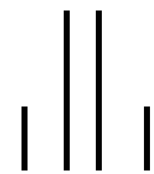
Detail on Additional Stressor

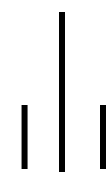
The additional stressor is constructed within the current framework of 4 impulses at time intervals of 0.75UI and weights of A1,A2,A3,A4.

1st approach (JSASYM1): set A2=A3 & A1=A4, and adjust A1&A4.



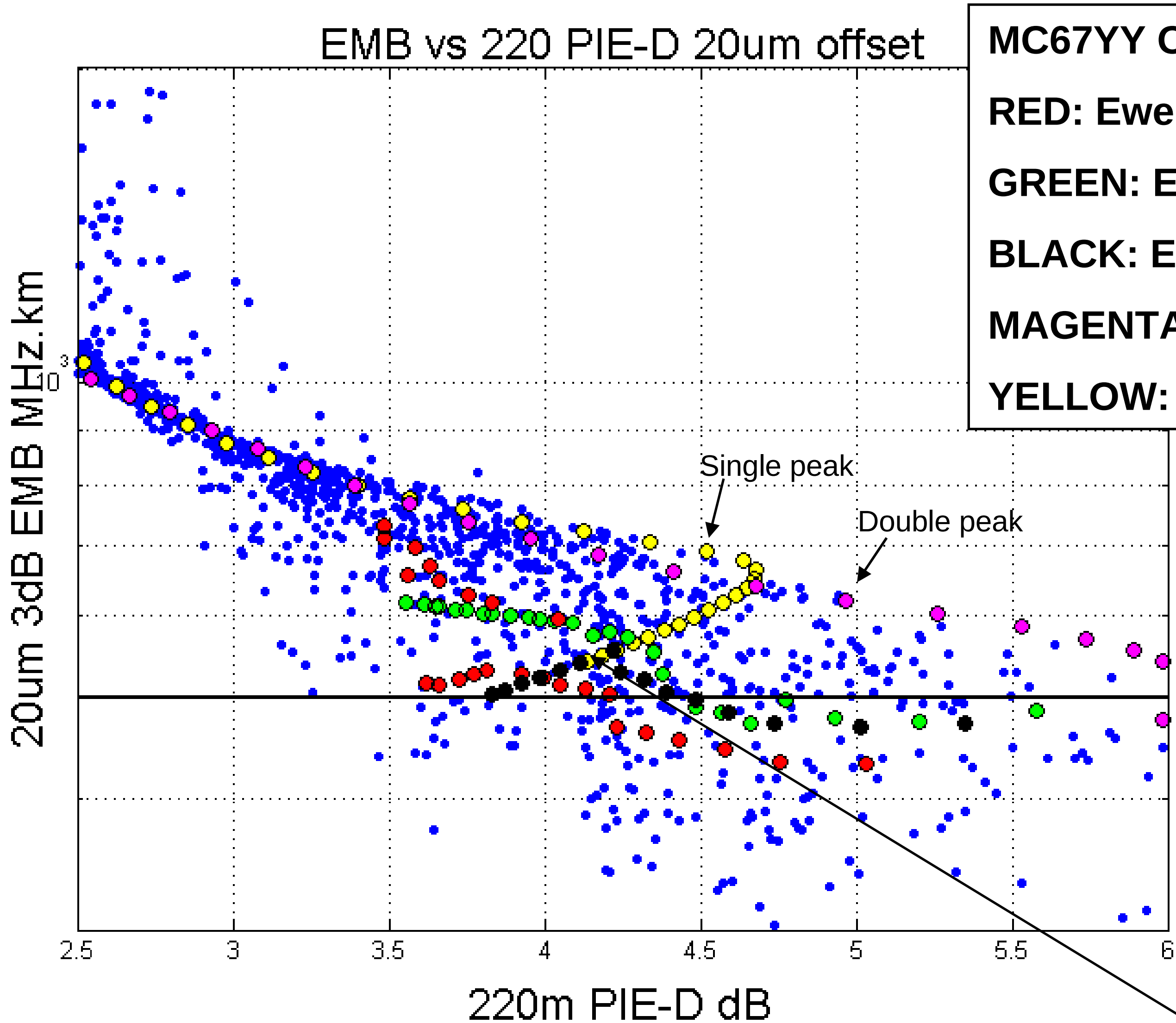
Double Peak

2nd approach (JSASYM2, JSASYM2b): set A1 = 0 and A2 = A4, and adjust A2. This approach matches some of the John Ewen “split symmetric” stressors if A2 is large enough, but in fact the largest PIE-D comes with A2 at a lower level.



Single Peak

220m EMB vs. PIE-D & JSAsym1, JSAsym2



MC67YY OM1 data set.

RED: Ewen precursor set

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MAGENTA: JSA symmetric set 1

YELLOW: JSA sym set 2, 2b

JSASYM2,2b matches Ewen split sym as side pulses increase

Discussion

The boundary of the region simulated by the MC67YY data set with a 20um launch is determined by pulses similar to can be constructed with the 4-peak stressor, either with a 3peak structure with a mean peak & 2 equal side peaks, or a 4 peak structure with 2 equal center peaks and 2 equal side peaks.

This is consistent with the 2001 TIA modeling of OM3 fibers for unequalized links at 850nm 300m 10Gb/s, where the boundary of the 3dB EMB, ISI distribution was determined by pulses whose FFT was similar to that of a double pulse.

Recommendation

Include a stressor representative of the symmetric near-Gaussian pulse seen with offset launches. The stressor becomes even more critical for 300m cases as seen in the backup slides.

The recommended stressor is the “double peak” example on slide 5with a PIE-D and PIE(12,5) of 4.4 and a BW of ~660MHz.km.

Backup Slides

A1-A2-A3-A4 weights, PIE-Ds, and EMBs for JSAsym1, JSAsym2, JSAsym2b

300m examples: PIE-D(220m) vs PIE-D(300m)

Finite Equalizer PIE(12,5) results

Plots using FWQM or “energy outside bit window”

Plots for 4um, 5um offset for comparison.

JSASYM1 weights

Index	Δt	A1	A2	A3	A4	PIE-D	EMB
1	0.750	0.000	0.500	0.500	0.000	2.54	1375
2	0.750	0.010	0.490	0.490	0.010	2.67	1328
3	0.750	0.020	0.480	0.480	0.020	2.80	1280
4	0.750	0.030	0.470	0.470	0.030	2.93	1230
5	0.750	0.040	0.460	0.460	0.040	3.08	1181
6	0.750	0.050	0.450	0.450	0.050	3.23	1133
7	0.750	0.060	0.440	0.440	0.060	3.39	1088
8	0.750	0.070	0.430	0.430	0.070	3.57	1045
9	0.750	0.080	0.420	0.420	0.080	3.75	1004
10	0.750	0.090	0.410	0.410	0.090	**3.96**	**967**
11	0.750	0.100	0.400	0.400	0.100	4.18	933
12	0.750	0.110	0.390	0.390	0.110	4.42	901
13	0.750	0.120	0.380	0.380	0.120	4.68	872
14	0.750	0.130	0.370	0.370	0.130	**4.97**	**845**
15	0.750	0.140	0.360	0.360	0.140	5.26	821
16	0.750	0.150	0.350	0.350	0.150	5.53	798
17	0.750	0.160	0.340	0.340	0.160	5.74	776
18	0.750	0.170	0.330	0.330	0.170	5.89	757
19	0.750	0.180	0.320	0.320	0.180	5.99	738
20	0.750	0.190	0.310	0.310	0.190	6.05	721
21	0.750	0.200	0.300	0.300	0.200	6.08	705
22	0.750	0.210	0.290	0.290	0.210	6.09	689
23	0.750	0.220	0.280	0.280	0.220	**6.07**	**675**
24	0.750	0.230	0.270	0.270	0.230	6.04	662
25	0.750	0.240	0.260	0.260	0.240	5.99	649

EMBs are for 300m; to convert to 220m multiply by 0.733

(example: stressor 10 still has a 220m PIE-D of 3.96 but now corresponds to a fiber with BW of 709MHz.km)

JSAsym2 weights

Index	Δt	A1	A2	A3	A4	PIE-D	3dB EMB
1	0.750	0.000	0.005	0.990	0.005	1.265	8978
2	0.750	0.000	0.010	0.980	0.010	1.297	8978
3	0.750	0.000	0.020	0.960	0.020	1.363	8977
4	0.750	0.000	0.030	0.940	0.030	1.430	8977
5	0.750	0.000	0.040	0.920	0.040	1.499	8977
6	0.750	0.000	0.050	0.900	0.050	1.570	8976
7	0.750	0.000	0.060	0.880	0.060	1.643	8976
8	0.750	0.000	0.070	0.860	0.070	1.718	8976
9	0.750	0.000	0.080	0.840	0.080	1.795	8976
10	0.750	0.000	0.090	0.820	0.090	1.875	8975
11	0.750	0.000	0.100	0.800	0.100	1.957	8975
12	0.750	0.000	0.110	0.780	0.110	2.042	8975
13	0.750	0.000	0.120	0.760	0.120	2.130	8974
14	0.750	0.000	0.130	0.740	0.130	2.222	1804
15	0.750	0.000	0.140	0.720	0.140	2.316	1625
16	0.750	0.000	0.150	0.700	0.150	2.415	1511
17	0.750	0.000	0.160	0.680	0.160	2.518	1424
18	0.750	0.000	0.170	0.660	0.170	2.625	1353
19	0.750	0.000	0.180	0.640	0.180	2.738	1294
20	0.750	0.000	0.190	0.620	0.190	2.856	1242
21	0.750	0.000	0.200	0.600	0.200	2.981	1197
22	0.750	0.000	0.210	0.580	0.210	3.113	1157
23	0.750	0.000	0.220	0.560	0.220	3.254	1121
24	0.750	0.000	0.230	0.540	0.230	3.404	1088
25	0.750	0.000	0.240	0.520	0.240	3.565	1059

JSAsym2 and JSAsym2b have the same structure, JSAsym2b has the lower EMB end of the curve.

EMBs are for 300m; to convert to 220m multiply by 0.733

(example: stressor 10 still has a 220m PIE-D of 3.96 but now corresponds to a fiber with BW of 709MHz.km)

JSAsym2b weights

Index	Δt	A1	A2	A3	A4	PIE-D	3dB EMB
1	0.750	0.000	0.122	0.756	0.122	2.148	8974
2	0.750	0.000	0.124	0.752	0.124	2.167	8974
3	0.750	0.000	0.126	0.748	0.126	2.185	1946
4	0.750	0.000	0.128	0.744	0.128	2.203	1862
5	0.750	0.000	0.135	0.730	0.135	2.269	1701
6	0.750	0.000	0.250	0.500	0.250	3.739	1031
7	0.750	0.000	0.260	0.480	0.260	3.927	1006
8	0.750	0.000	0.270	0.460	0.270	4.128	983
9	0.750	0.000	0.280	0.440	0.280	4.337	961
10	0.750	0.000	0.290	0.420	0.290	4.523	940
11	0.750	0.000	0.300	0.400	0.300	4.639	921
12	0.750	0.000	0.310	0.380	0.310	4.679	903
13	0.750	0.000	0.320	0.360	0.320	4.674	886
14	0.750	0.000	0.330	0.340	0.330	4.649	870
15	0.750	0.000	0.340	0.320	0.340	4.613	855
16	0.750	0.000	0.350	0.300	0.350	4.571	841
17	0.750	0.000	0.360	0.280	0.360	4.527	827
18	0.750	0.000	0.370	0.260	0.370	4.480	814
19	0.750	0.000	0.380	0.240	0.380	4.432	802
20	0.750	0.000	0.390	0.220	0.390	4.383	790
21	0.750	0.000	0.400	0.200	0.400	4.334	779
22	0.750	0.000	0.410	0.180	0.410	4.285	768
23	0.750	0.000	0.420	0.160	0.420	4.235	758
24	0.750	0.000	0.430	0.140	0.430	4.185	748
25	0.750	0.000	0.440	0.120	0.440	4.135	738

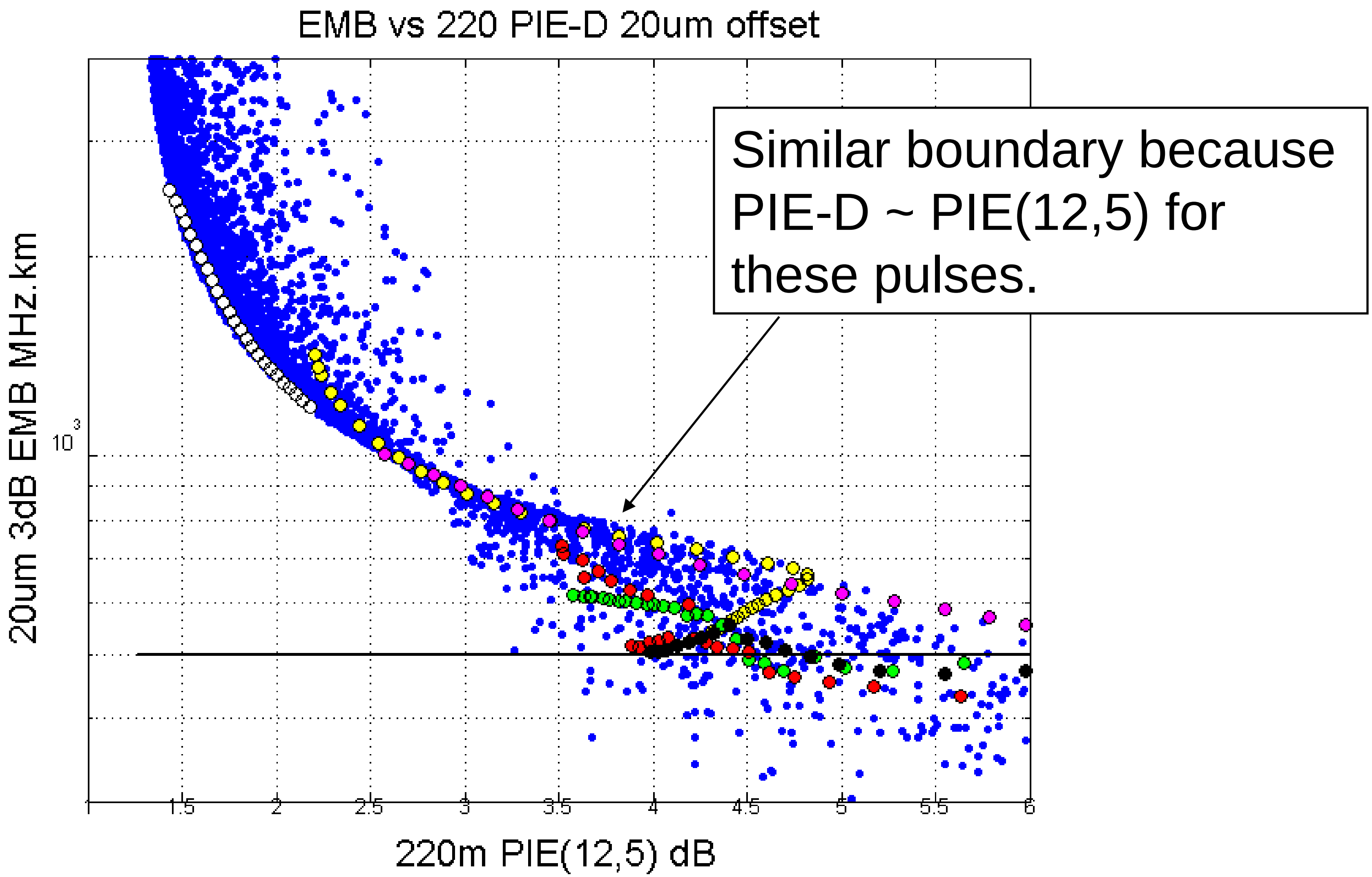
EMBs are for 300m; to convert to 220m multiply by 0.733

(example: stressor 10 still has a 220m PIE-D of 3.96 but now corresponds to a fiber with BW of 709MHz.km)

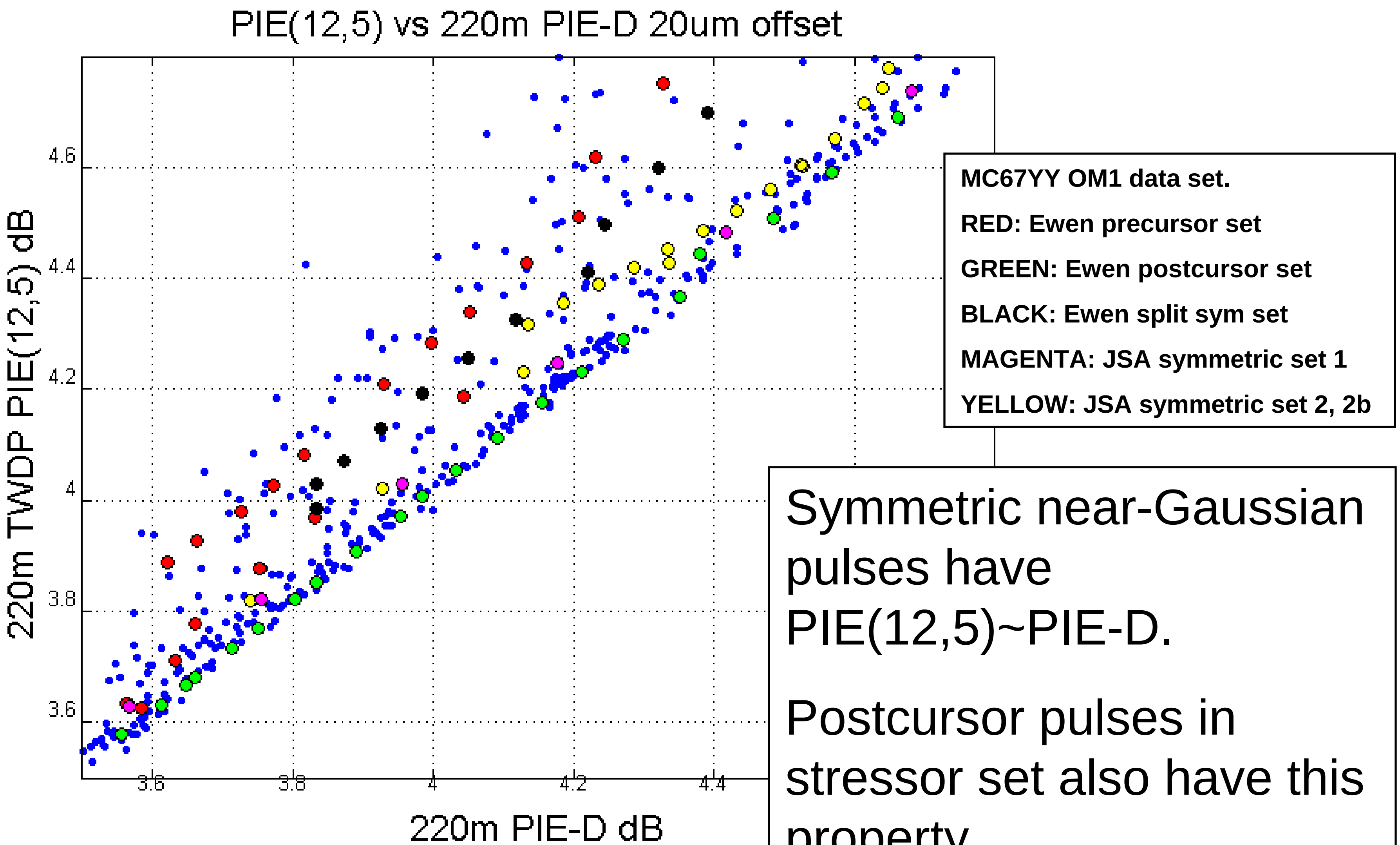
Backup Slides

Plots with PIE(12,5)

Using PIE(12,5) instead of PIE-D



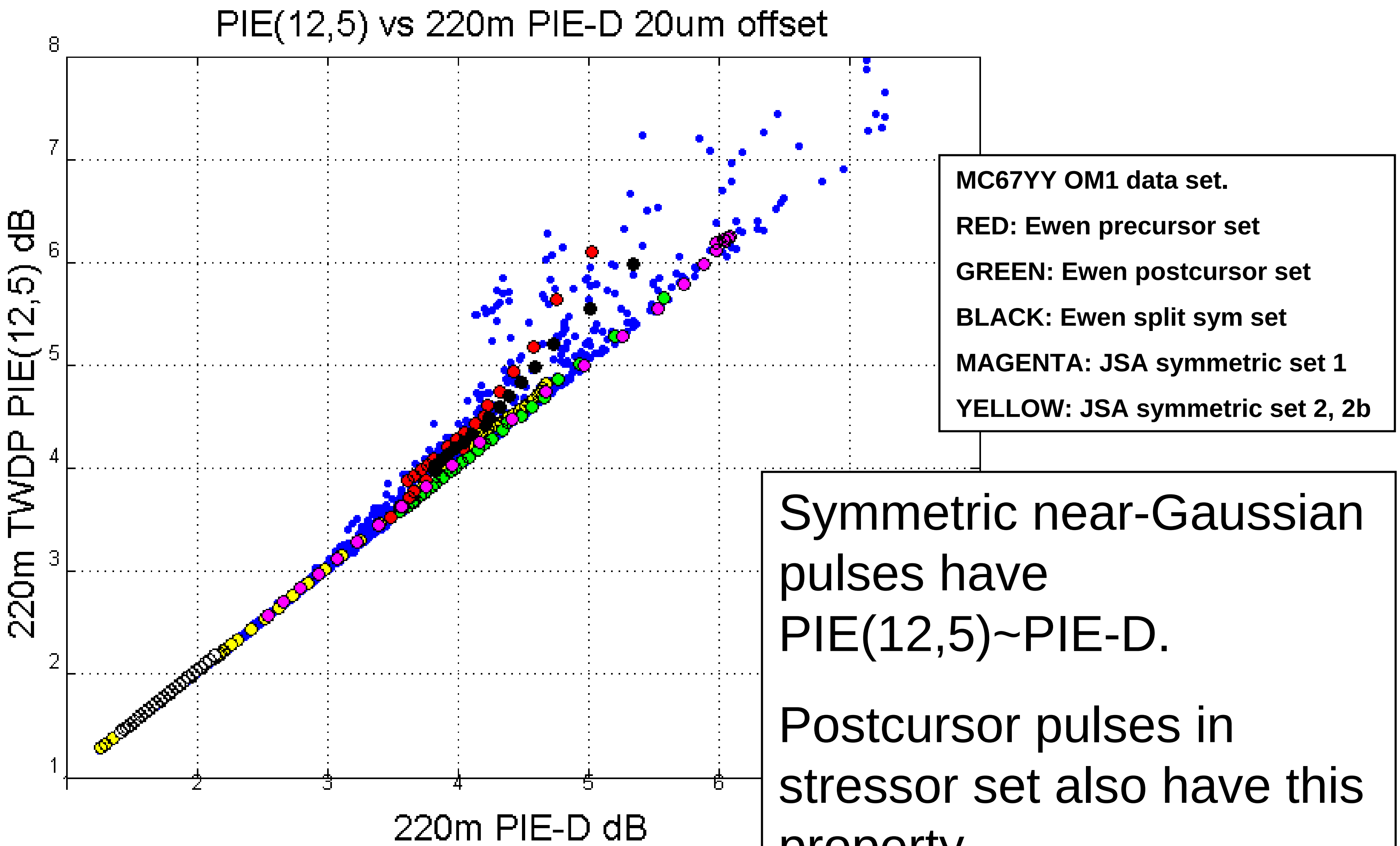
PIE(12,5) vs. PIE-D 20um offset pulses.



Symmetric near-Gaussian pulses have PIE(12,5)~PIE-D.

Postcursor pulses in stressor set also have this property.

PIE(12,5) vs. PIE-D 20um offset pulses.



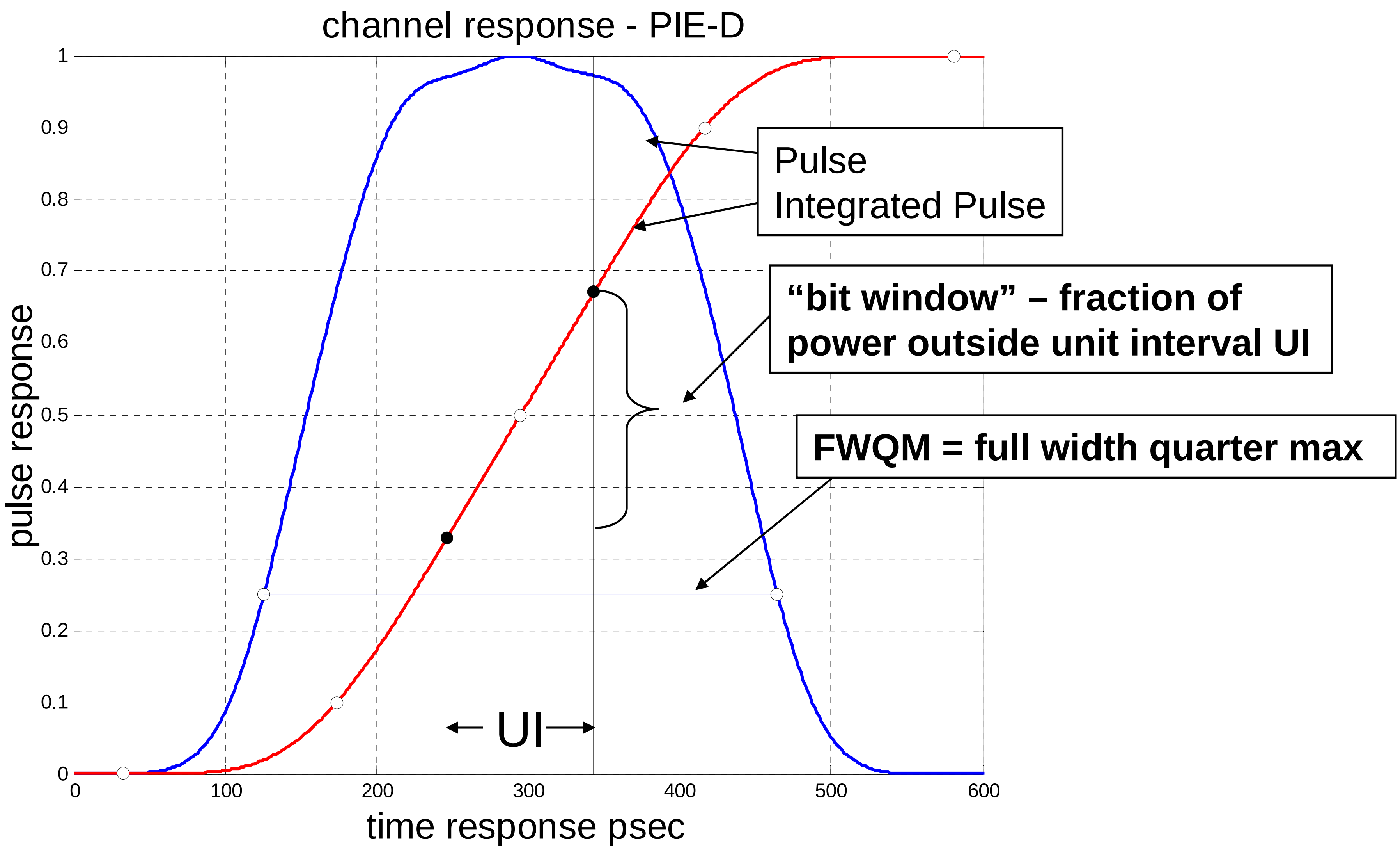
Symmetric near-Gaussian pulses have PIE(12,5)~PIE-D.

Postcursor pulses in stressor set also have this property.

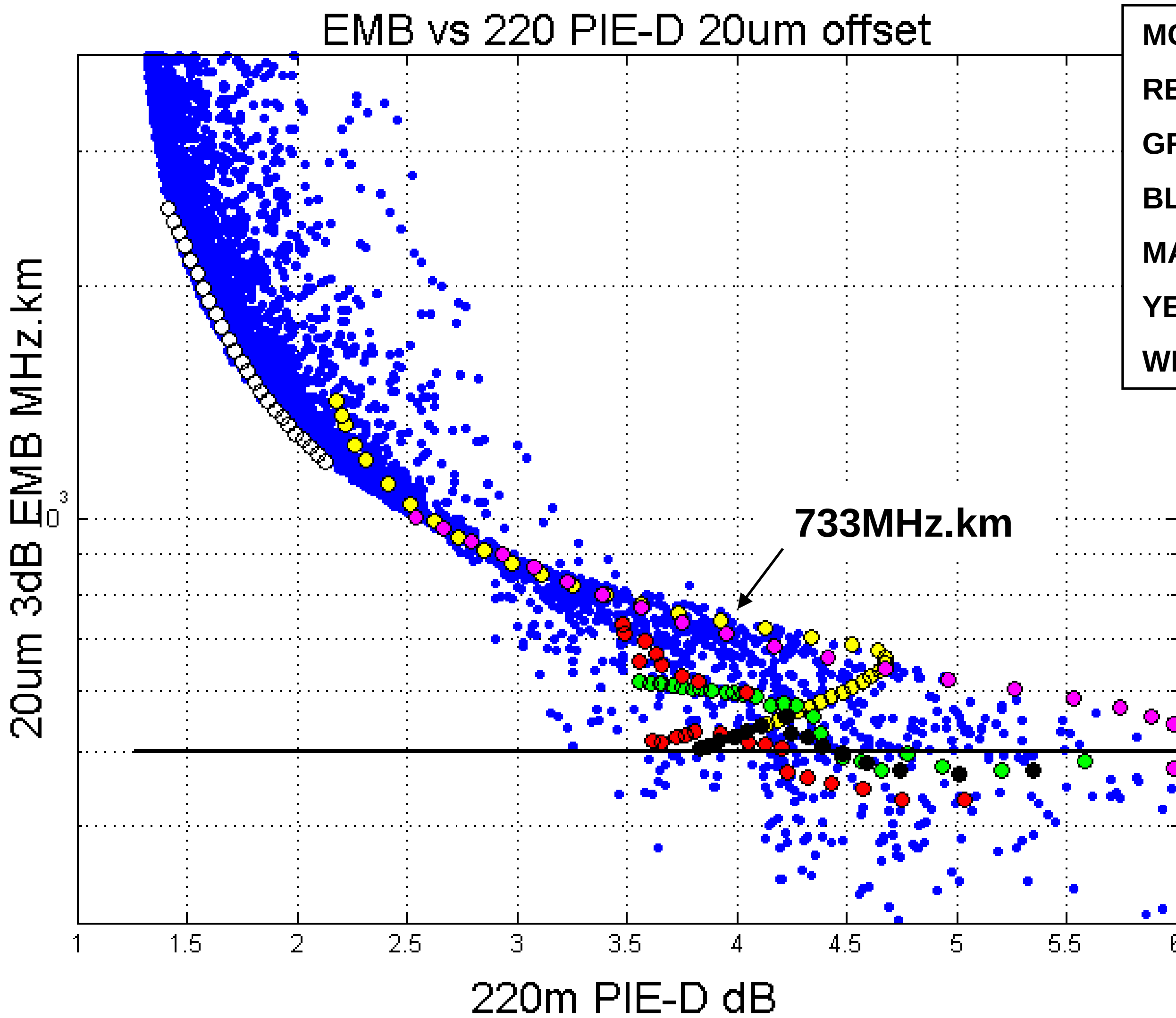
Backup Slides

Plots with FWQM or “energy outside of bit window” as alternatives to 3dB BW

Example plot with bit window & FWQM



220m EMB vs. PIE-D & JSAsym1, JSAsym2



MC67YY OM1 data set.

RED: Ewen precursor set

GREEN: Ewen postcursor set

BLACK: Ewen split sym set

MAGENTA: JSA symmetric set 1

YELLOW: JSA sym set 2, 2b

WHITE: JSAsym1 & 0.30UI spacing

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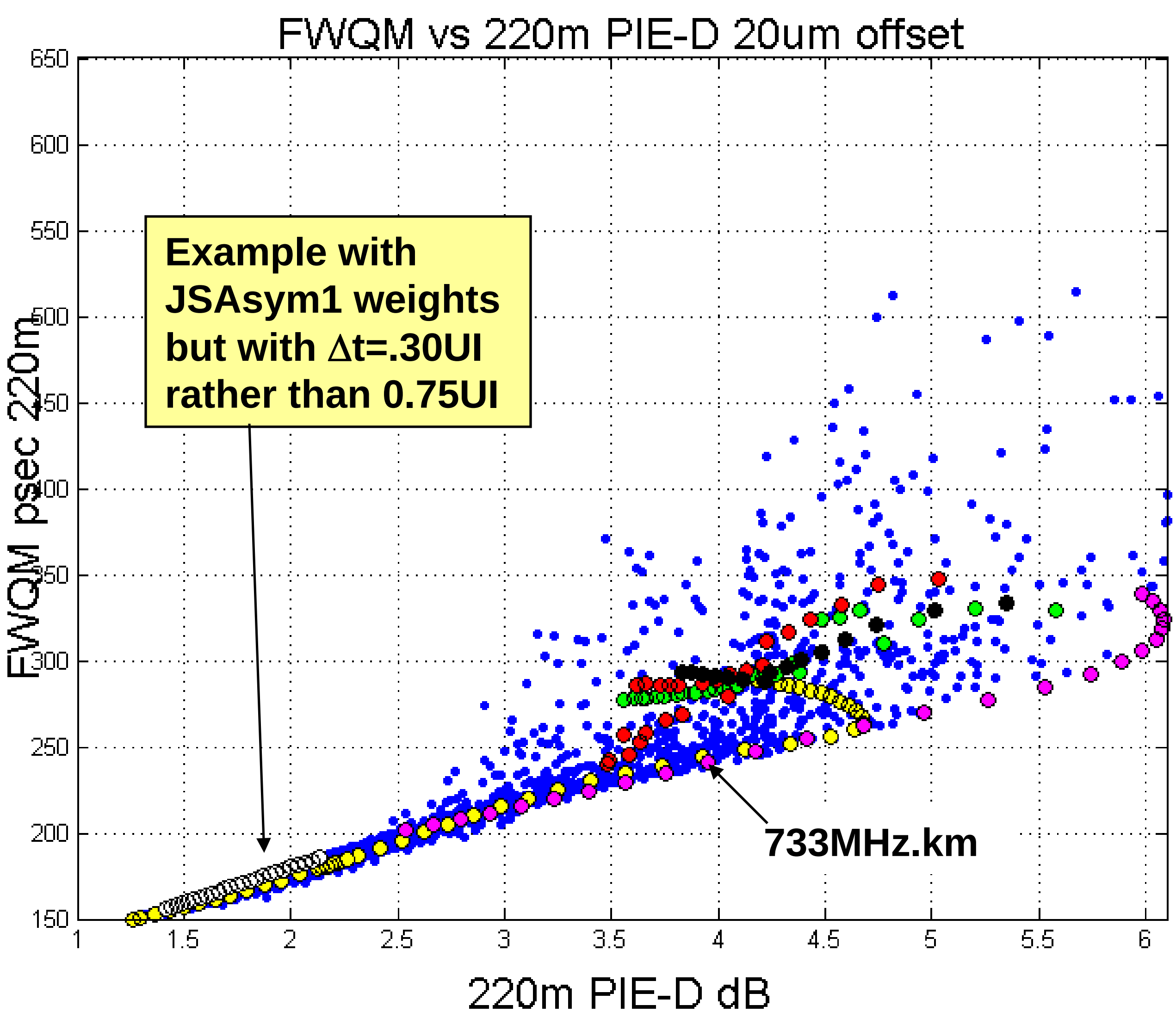
Example 2 20um offset FWQM vs. PIE-D (220m)



BLUE: MC67YY OM1 data set.

RED: Ewen precursor set

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BLACK: Ewen split sym set

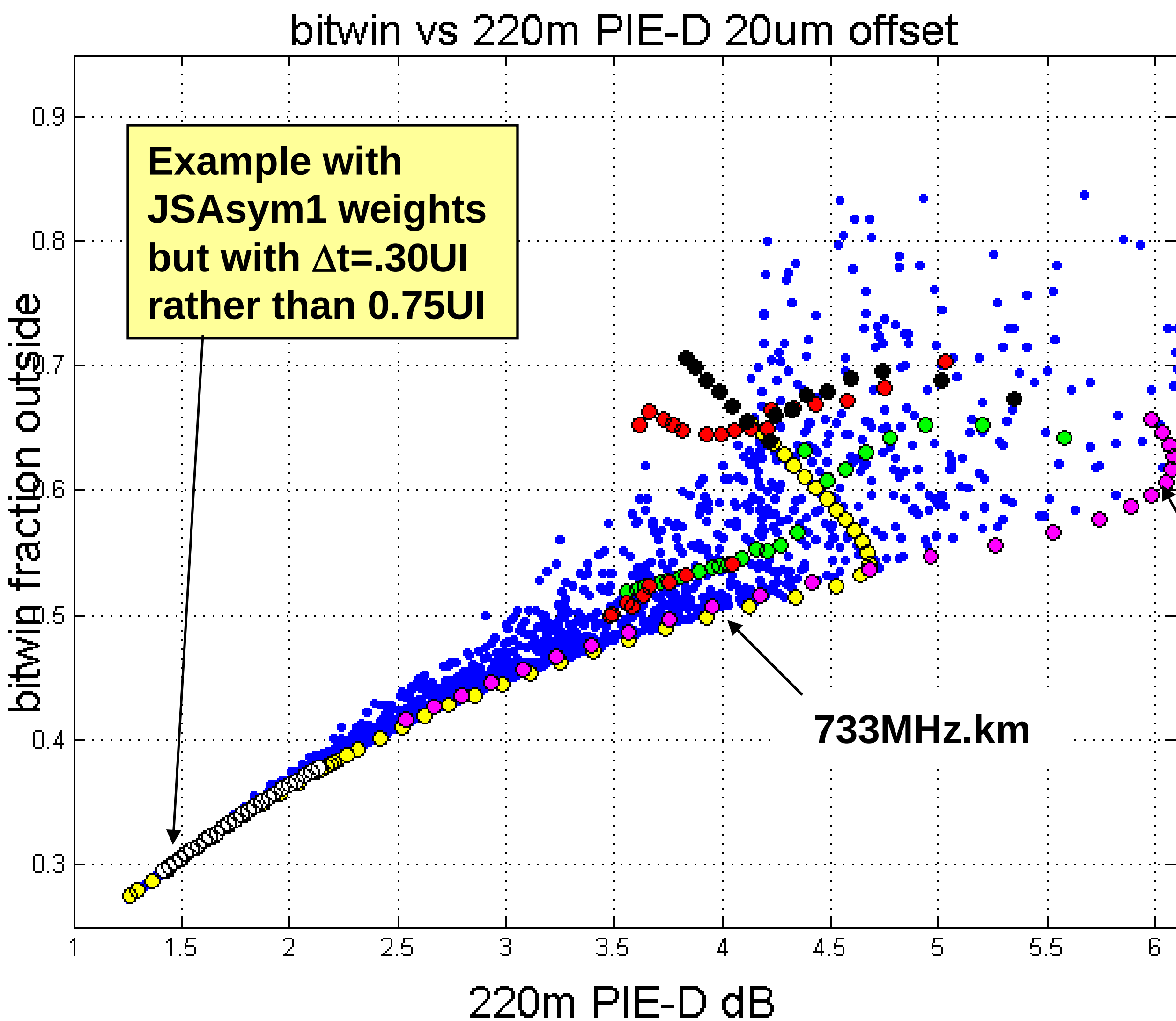
MAGENTA: JSA symmetric set 1

YELLOW: JSA sym2 & JSAsym2b

WHITE: JSAsym1 & 0.30UI spacing

Pulse becomes "square wave" not "Gaussian", and easier to equalizer with PIE-D.

Example 1 20um offset EMB vs. PIE-D (220m)



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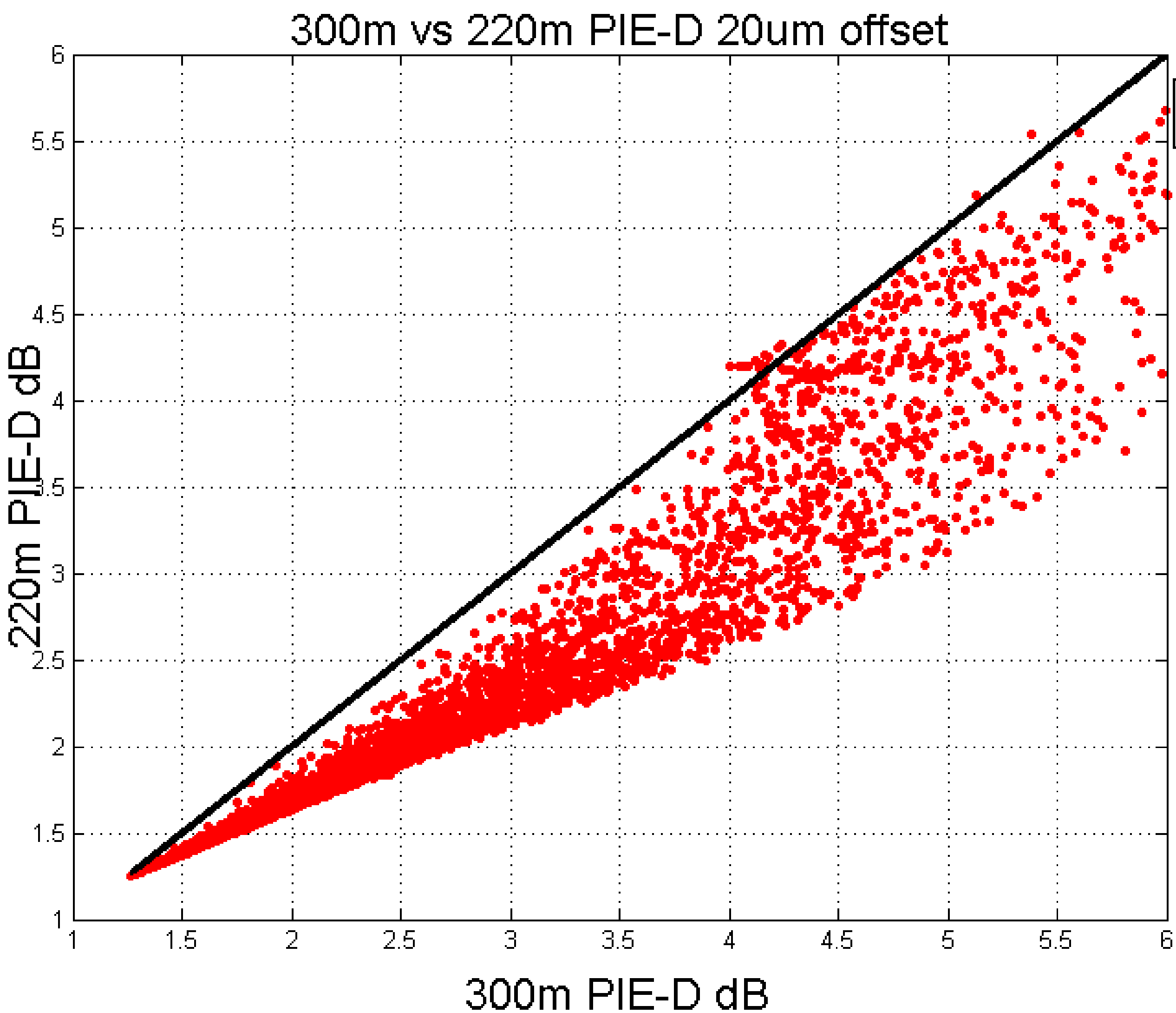
Backup Slides

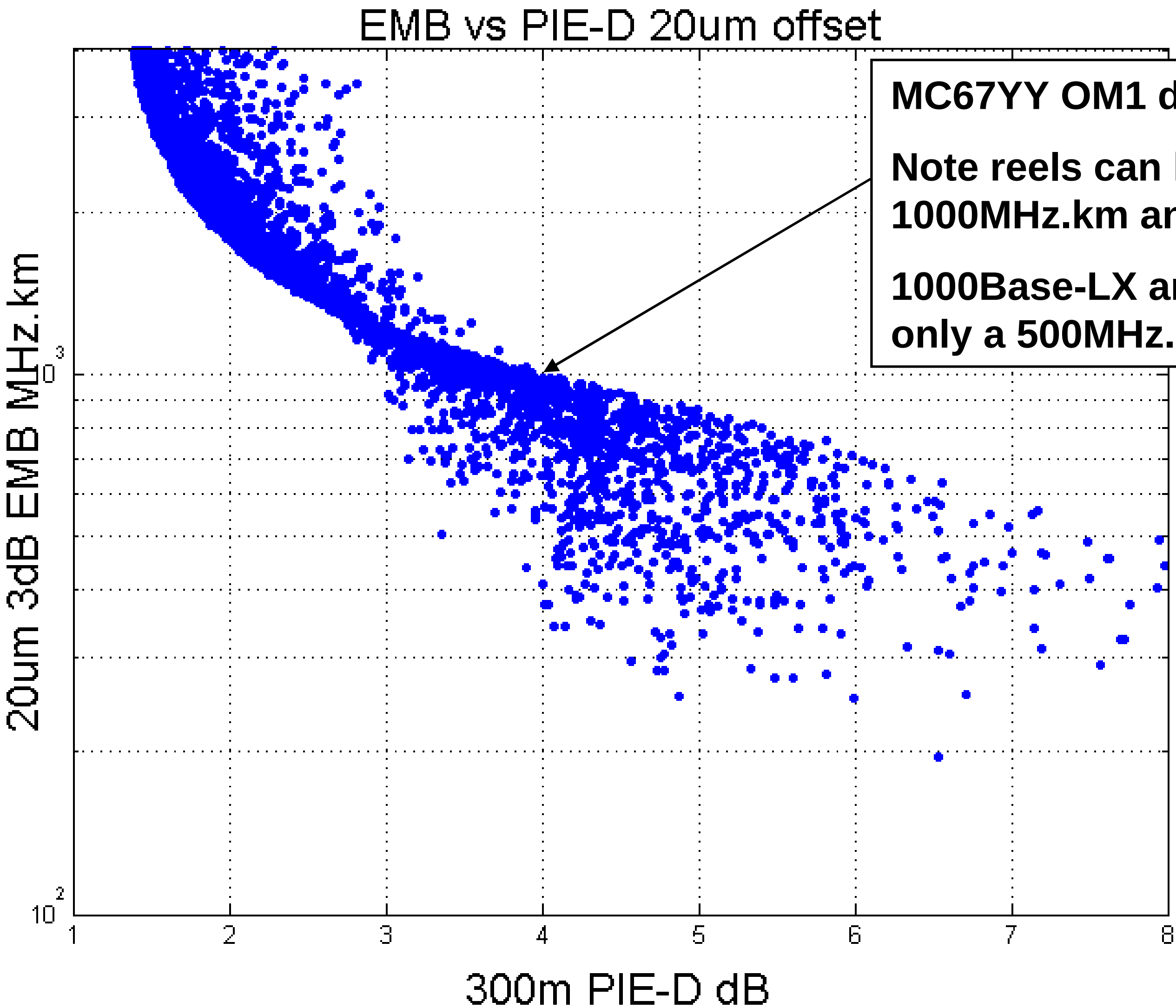
PIE-D(300m)

220m PIE-D vs. 300m PIE-D



MC67YY OM1 data set.

20um offset EMB vs. PIE-D (300m)

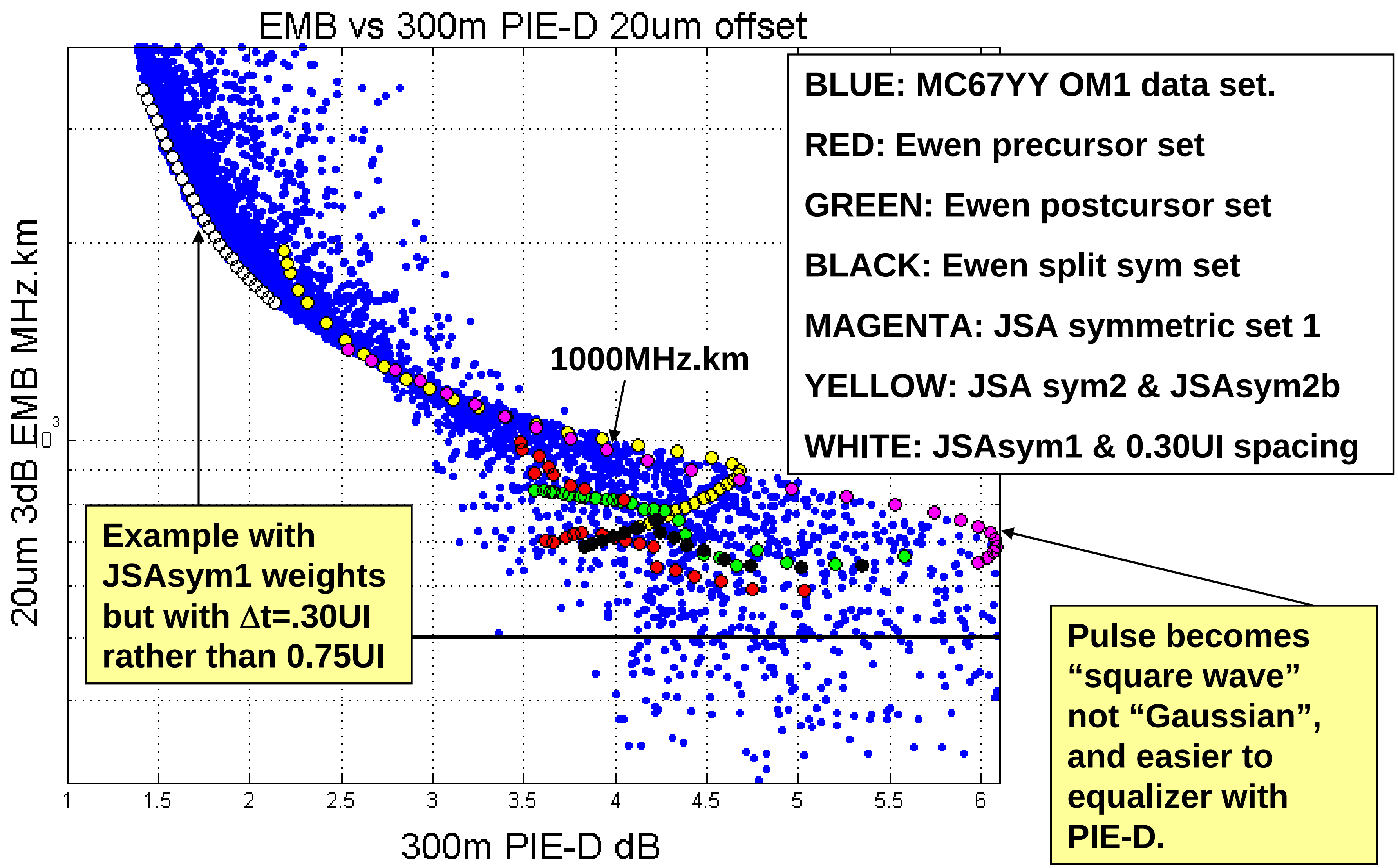


MC67YY OM1 data set.

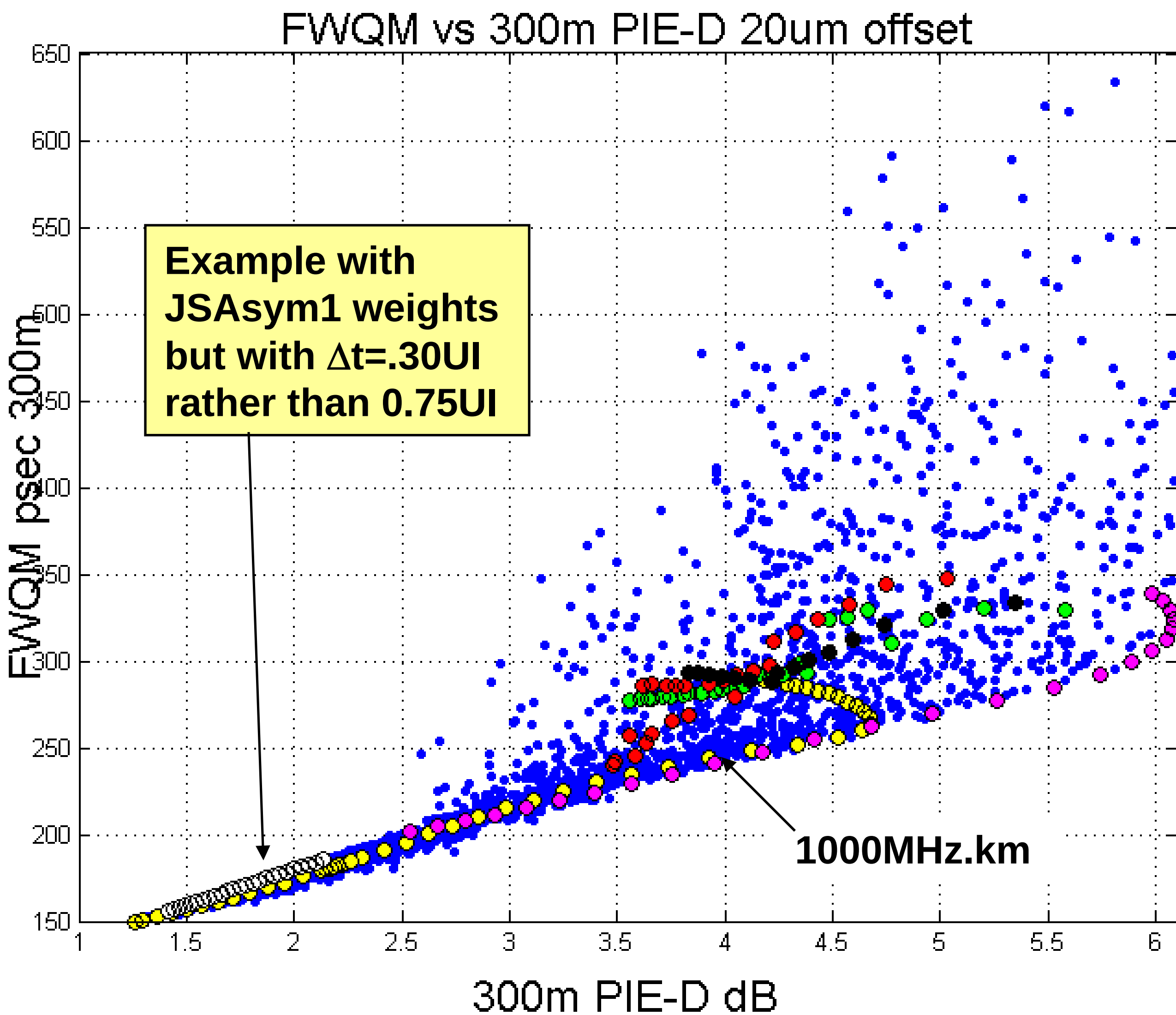
Note reels can have an EMB of almost 1000MHz.km and fail a 4dB PIE-D

1000Base-LX and GBASE LX-4 require only a 500MHz.km offset BW

Example 1 20um offset EMB vs. PIE-D (300m)



Example 2 20um offset FWQM vs. PIE-D (300m)



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BLACK: Ewen split sym set

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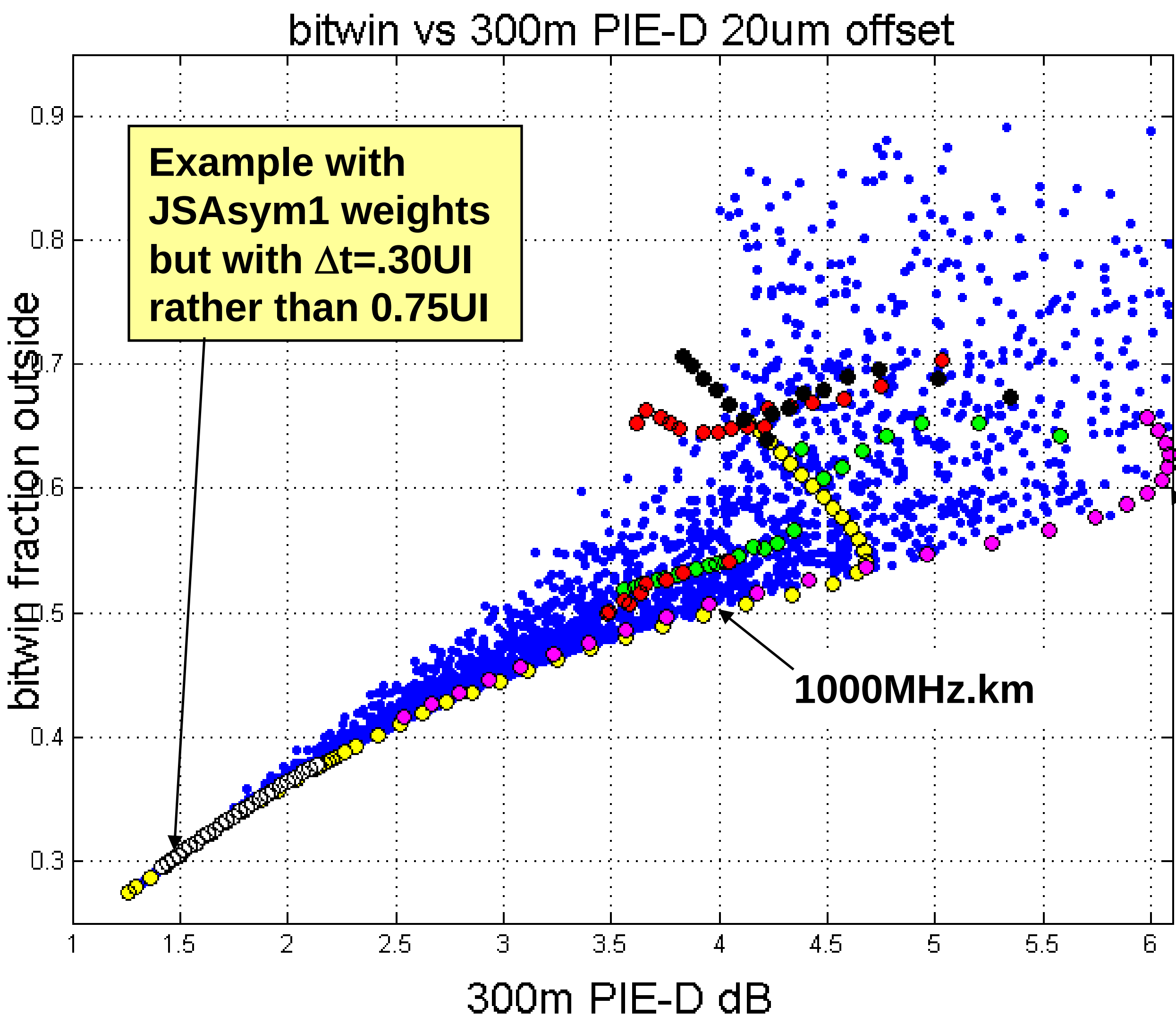
Pulse becomes "square wave" not "Gaussian", and easier to equalizer with PIE-D.

Example 1 20um offset EMB vs. PIE-D (300m)



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WHITE: JSAsym1 & 0.30UI spacing

Pulse becomes "square wave" not "Gaussian", and easier to equalizer with PIE-D.

Backup Slides

Center Launch Examples: 4um, 5um

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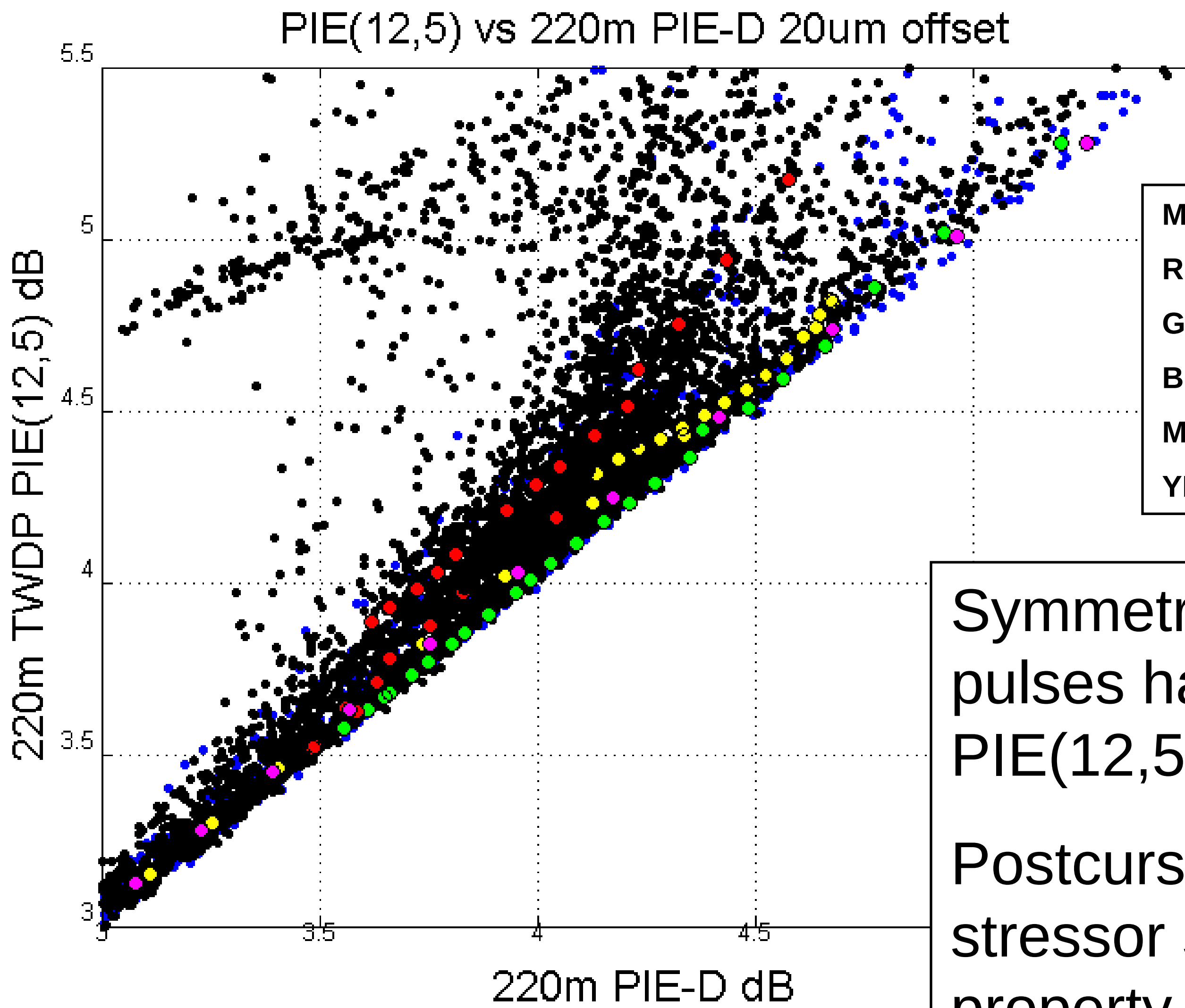
PIE(12,5) vs. PIE-D black=4um,5um pulses



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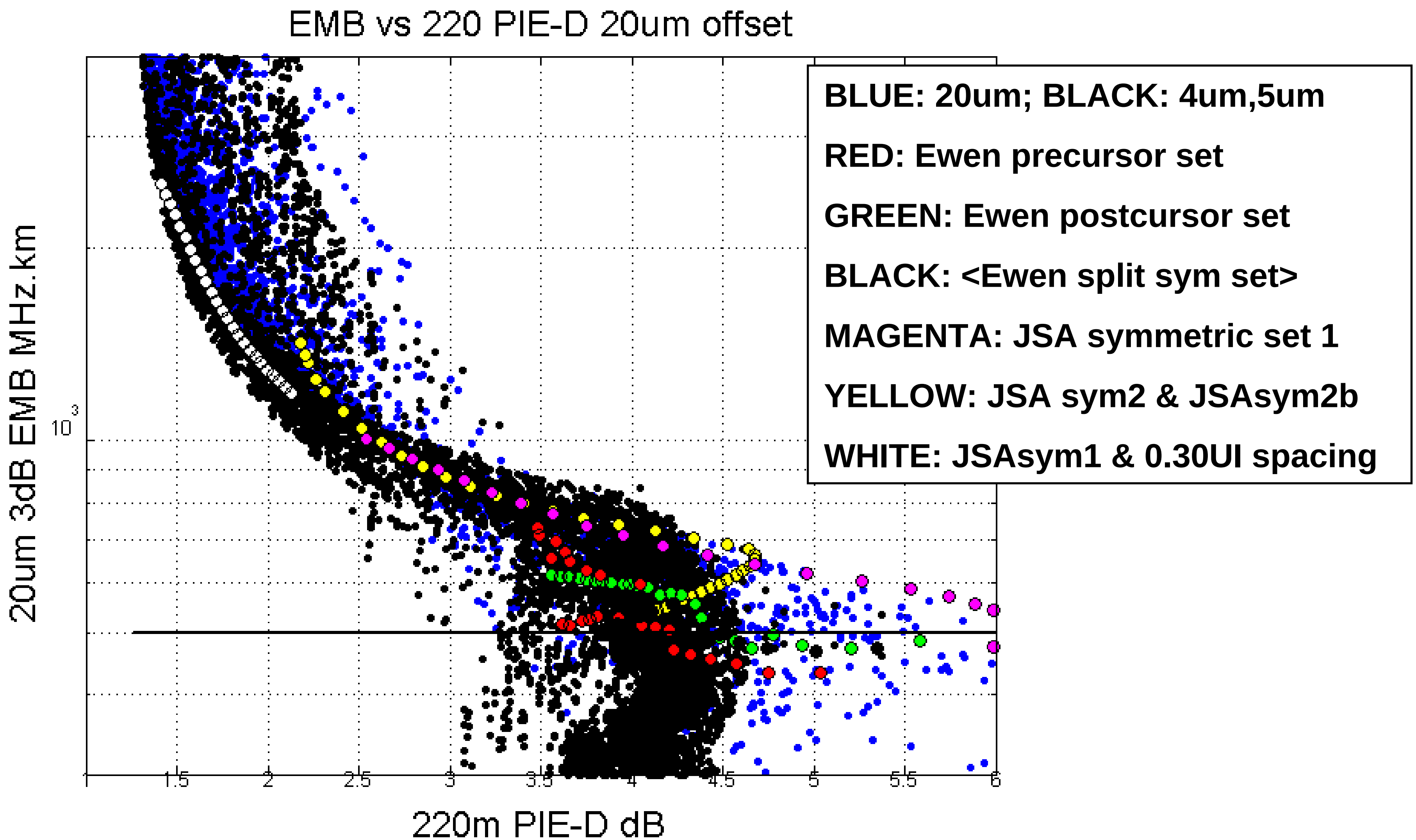
YELLOW: JSA symmetric set 2, 2b

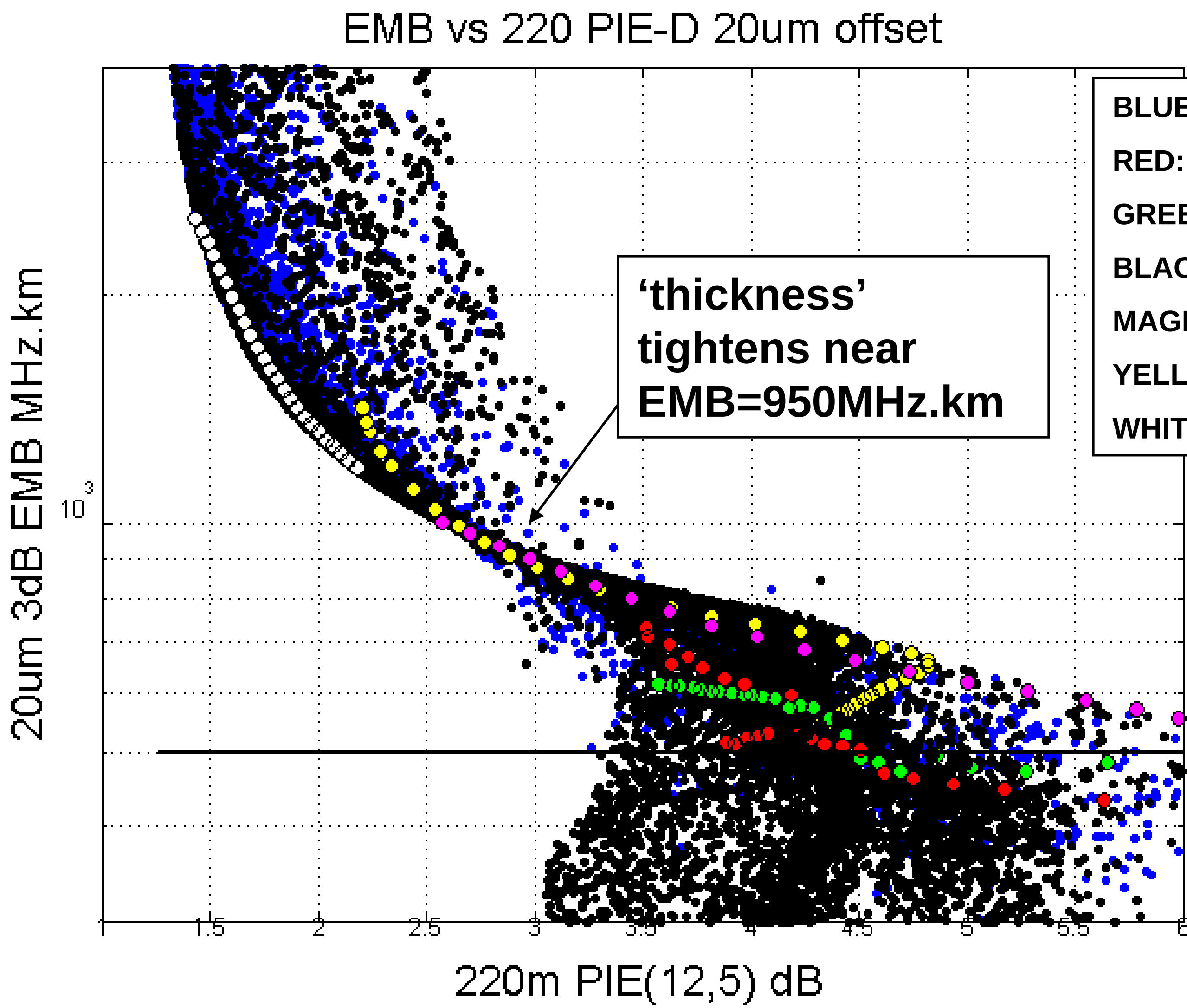
Symmetric near-Gaussian pulses have PIE(12,5)~PIE-D.

Postcursor pulses in stressor set also have this property.

4,5,20um offset EMB vs. PIE-D (220m)



4,5,20um offset EMB vs. PIE(12,5) (220m)



BLUE: 20um; BLACK: 4um,5um

RED: Ewen precursor set

GREEN: Ewen postcursor set

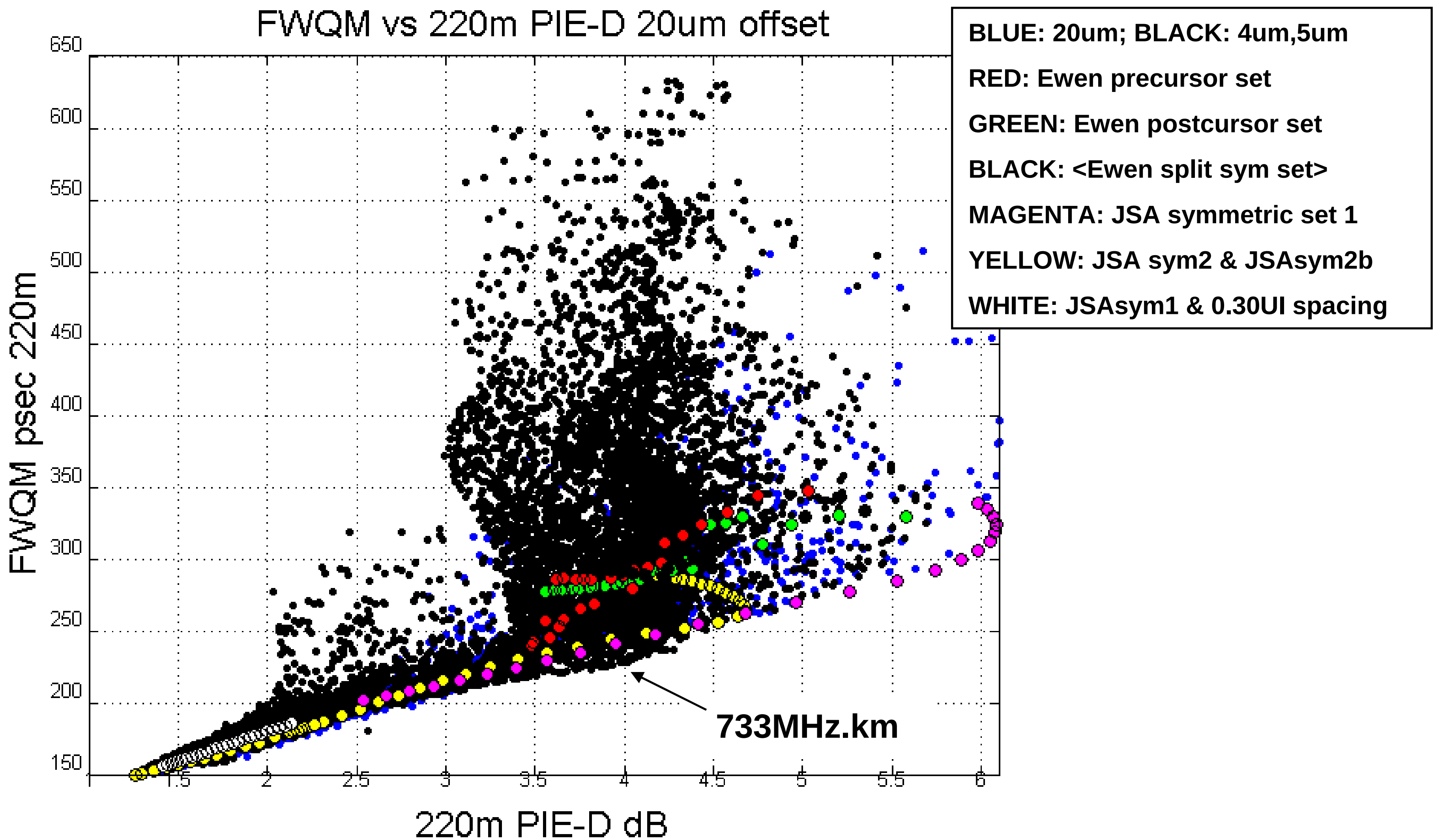
BLACK: <Ewen split sym set>

MAGENTA: JSA symmetric set 1

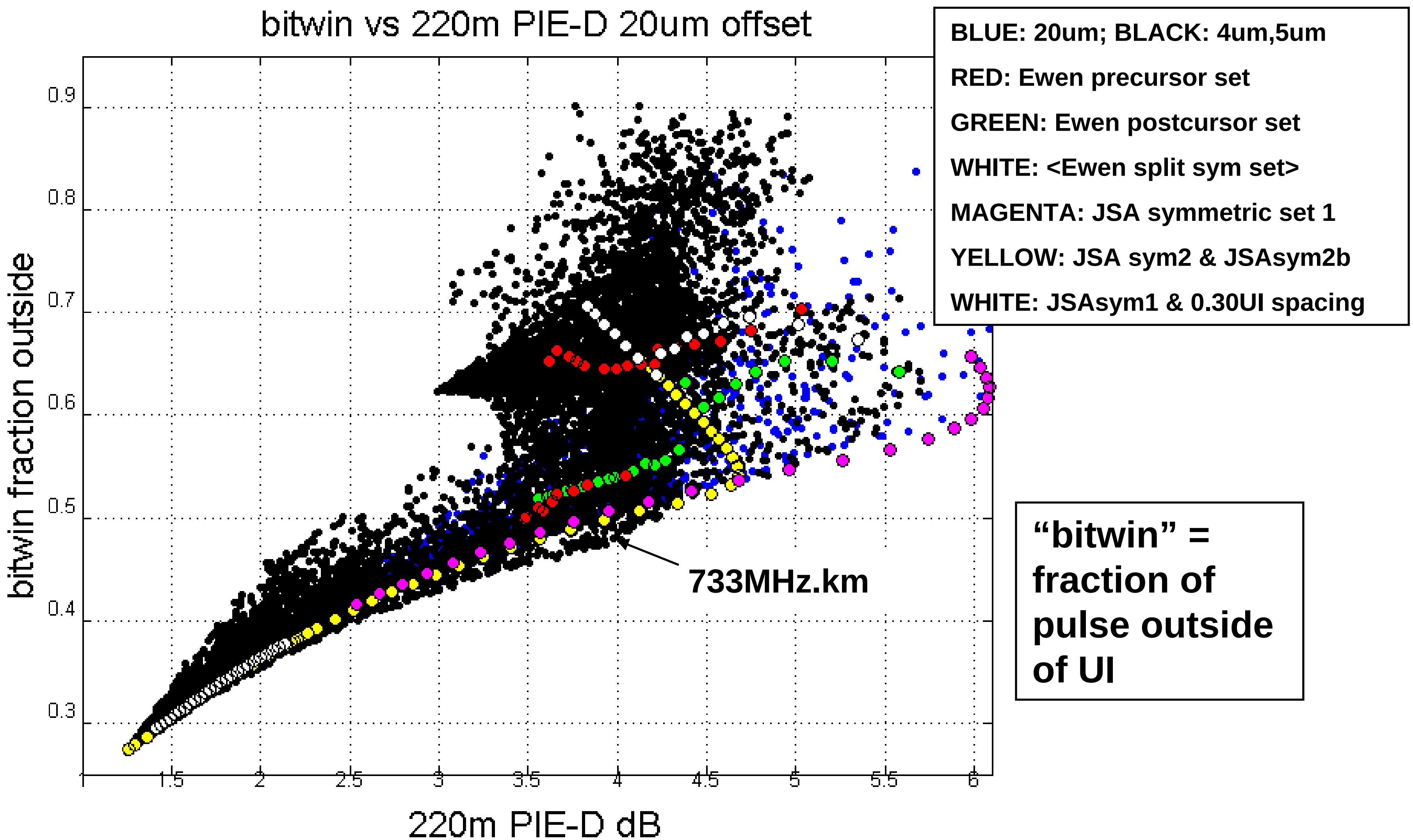
YELLOW: JSA sym2 & JSAsym2b

WHITE: JSAsym1 & 0.30UI spacing

4, 5, 20um offset FWQM vs. PIE-D (220m)

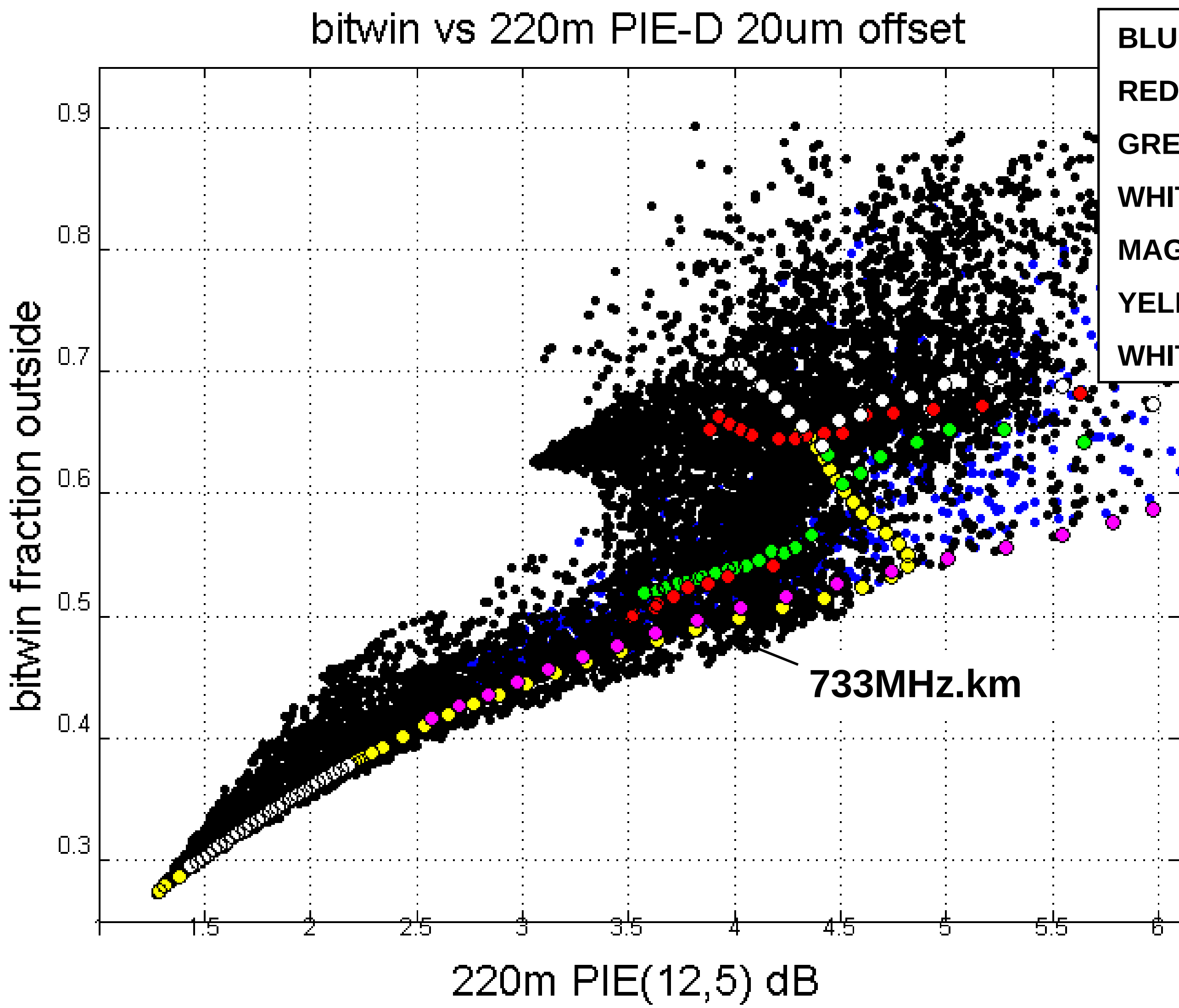


4, 5, 20um offset “bitwin” vs. PIE-D (220m)



“bitwin” = fraction of pulse outside of UI

4, 5, 20um offset “bitwin” vs. PIE(12,5) (220m)



BLUE: 20um; BLACK: 4um,5um
RED: Ewen precursor set
GREEN: Ewen postcursor set
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“bitwin” = fraction of pulse outside of UI