MARK 5 MEMO #043

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

Telephone: *978-692-4764*
Fax: *781-981-0590*

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TO: Mark 5 group

FROM: Alan E.E. Rogers

SUBJECT: Simulations of broadband delay measurements

Bill Petrachenko has evaluated the geodetic accuracy for various combinations of data rates and frequency coverage. Bill has shown that broadband systems which coherently combine several frequency bands to estimate the ionosphere corrected delay have great potential to improved accuracy over the current dual band system which only coherently averages each band separately. For simplicity I have chosen to evaluate Bill's system #5 with the following parameters:

Ant. Diam.	12 m
Efficiency	0.5
System noise	50 K (including atmosphere)
Data rate	2 Gbps
Frequency bands	2, 4, 5.5, 9 GHz
Bandwidth in each band	500 MHz (16×16 MHz channels spaced 32 MHz apart)

For this system I get the following results the rms delay precision using linear least squares without source structure:

For 1 J point source observed for 6os

Rms ps	Condition	Case
0.31	Fully coherent without ionosphere	A
0.40	Fully coherent with ionosphere	B
1.68	Also solving for a phase offset	C

Table 1. rms error estimates from linear least squares

Note: A we solve only for phase proportional to frequency

B we solve for linear phase plus phase which is inversely proportional to frequency

C an additional phase offset is estimated

At low SNR the estimation problem is non linear and the ambiguity function is needed to evaluate the probability that fringes will be obtained at an ambiguity which will result in a significant systematic error. For linear least squares the numbers in Table 1 would increase by a factor of 5 in going from a 1 J source to a 0.2 J source. However at 0.2 J the SNR calculated for 2 Gbps integrated for 6os is 16 which should provide a reliable detection in a fully coherent fringe in delay, dispersion and delay rate. To evaluate the probability of landing on an ambiguity I have simulated cases B and C for a source of 0.2, 0.1 and 0.075 J.

Rms ps	Source J	SNR	Comments	Case
2.6	0.2	17		B
5.0	0.1	8		B
20	0.075	6	Occasional ambiguity	B
5	0.2	16		C
10	0.1	8		C
54	0.075	6	Occasional ambiguity	C

Table 2. Simulations without source structure

Figure 1 shows the delay/dispersion ambiguity function for Case B.

Next I introduced a random phase error in each band with an rms of 5 ps to simulate the effect of source with structure index 2.

Rms ps	Source J	SNR	Comments	Case
7	0.2	17		B
16	0.1	8		B
44	0.075	6		B
9	0.2	17		C
18	0.1	8		C
55	0.075	6	Several ambiguities	C

Table 3. Simulations with 5 ps rms errors in each band to simulate weak source structure.

Next I used source structure data for baseline angle of zero from Arthur Niell

Source	Case B ps	Case C ps	Case D ps	Comments
0014p813	1.7	4.5	45	
0113m118	107	107	145	Poor
0149p218	0.7	3.2	43	
0202p149	0.5	0.8	58	
0248p430	263	270	171	Poor
2143m156	91	75	169	Poor
2143m 156_2	2.4	8.6	50	2-16 GHz
2143m156_2	12	12	91	0.2J

Table 4 Simulations using source structure information from AEN

Case B: Fully coherent incl. ion. Case C: + phase offset Case D: individuals bands

Given the large structure effects for sources 0113m118 and 0248p430 I added an analysis (case D) which used only the group delays from the 4 individual bands to estimate an ionosphere free observable.

Source 2143m156 was reanalyzed as 2143m156_1 by changing the frequency sequence to include all frequencies from 2 to 16 GHz in steps of 0.1 GHz (still with a fixed total 2 Gbps). In this case the correct dispersion ambiguity is always found. Another "fix" (see 2143m156-2) to be ambiguity problem with this source is to increase the flux of 0.2 Jy

Conclusions

My results for Case B given in Table 1 are in fairly close agreement with Bill Petrachenko's. The simulation results of tables 2 and 3 shows that ambiguities should not be a problem at high SNR even with some source structure. The simulations results of table 4 show that some sources have sufficient structure to largely remove the advantages of a broadband coherent system. Presumably these sources, which have significant structure, can be avoided.

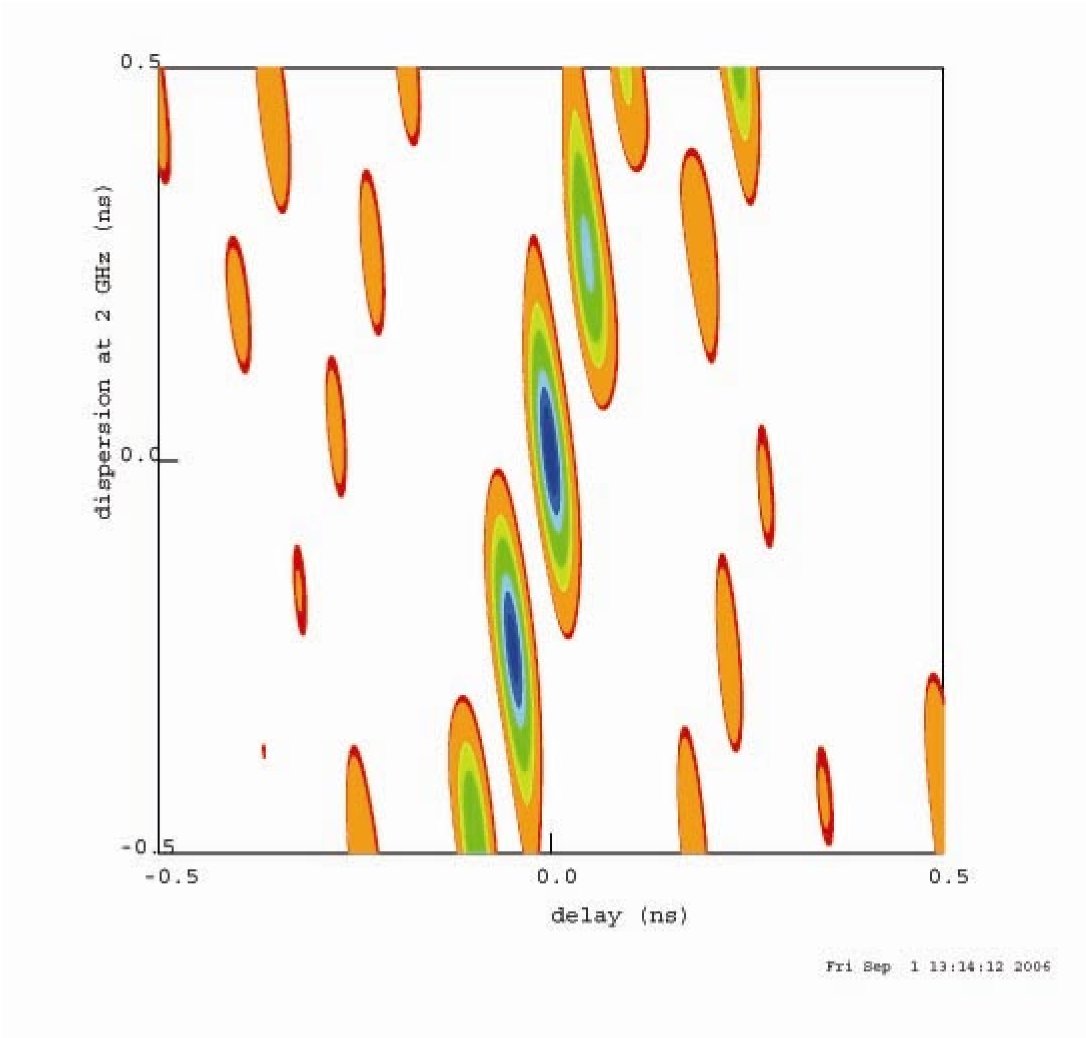

Figure 1. Delay/dispersion ambiguity function. (Only values above 0.5 are plotted).