VLB ARRAY MEMO No. 513

(851203)

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Area Code 617
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To: VLBA

From: A.E.E. Rogers

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Subject: Dual Band (S/X) Bandwidth Synthesis with 8 Channels

The present POLARIS/NASA CDP observing uses the following non-redundant frequency sequences:

8210.99, 8220.99, 8250.99, 8310.99, 8420.99, 8500.99, 8550.99, 8570.99 MHz
2217.99, 2222.99, 2237.99, 2267.99, 2292.99, 2302.99 MHz

These sequences of 8 channels at X-band and 6 channels at S-band have the following characteristics (see Clark et al., IEEE Transactions GE-23, pp 438-449, July 1985, for more details):

X-band	ambiguity spacing	100 nanosec
	spanned bandwidth	360 MHz
	rms spanned bandwidth	138 MHz
S-band	ambiguity spacing	200 nanosec
	spanned bandwidth	85 MHz
	rms spanned bandwidth	36 MHz

1-σ error in delay measurement = $1/(2\pi f$ r.m.s. X SNR) (where the SNR is for all channels (within one frequency band) added coherently)

If only 8 channels are available in the initial implementation of the VLBA we would have to use sequences such as:

8210.99, 8270.99, 8450.99, 8570.99 MHz
2212.99, 2227.99, 2272.99, 2302.99 MHz

These sequences have the following characteristics:

X-band	ambiguity spacing	16.67 nanosec
	spanned bandwidth	360 MHz
	r.m.s. spanned bandwidth	165 MHz
S-band	ambiguity spacing	66.67 nanosec
	spanned bandwidth	90 MHz
	r.m.s. spanned bandwidth	41 MHz

Comments and Discussion:

The ambiguity spacing is reduced when fewer frequencies are available. This is acceptable only if the ambiguities can be resolved by a priori information or the "single-band" delay. At S-band the ionosphere variations can be as large as 50 nanoseconds so the a priori information will be only marginally good enough to resolve the 66.67 nanosecond ambiguity. The amount of hand labor required to check that all of the ambiguities have been correctly resolved at this ambiguity spacing is prohibitive for routine operation. For the "single-band" delay the r.m.s. spanned bandwidth is the channel bandwidth divided by $\sqrt{12}$ so that for 4 MHz bandwidth the 1-sigma delay error is (138/SNR) nanoseconds and hence the "single-band" delay might be good enough to resolve the S-band ambiguities. This would need to be tested. At X-band the a priori information should be good enough to resolve the 16.67 nanosecond ambiguities, since the ionospheric and atmospheric delay uncertainties should be under 3 nanoseconds.

We therefore expect that dual band bandwidth synthesis would be marginal with only 8 channels. Fewer channels would pose serious problems unless frequency switching methods are used. Observations using 7 channels were tried using the Mark-III S/X system. These data were found to be very difficult to analyze due to ambiguities. Wider "single-band" channels could help but even 16 MHz [for which error = (34/SNR) nanoseconds] channel bandwidth is not good enough to resolve the ambiguities in a sequence of only 2 channels per band. If S/X is not available on the VLBA than a similar sequence could be devised for 5/15 GHz - however, S/X is the only dual band capability presently supported at other sites.

We are also concerned about questions of reliability. With only four channels, the failure of a single local oscillator, for example, would seriously degrade the delay resolution function. Six or eight channel operation is much less sensitive to the loss of a single channel.

Finally we are concerned about compatibility with currently operational Mark-III equipped observatories. About ten such observatories are in operation in the United States and five or ten more are in operation or under construction abroad. Cooperative observing programs with these observatories could significantly enhance the performance of the VLBA, particularly during the construction phase as the first few observatories become operational. Conversely, occasional use of individual VLBA antennas to supplement the existing national and international arrays could result in significant observational capability that would otherwise not be available. There are also 4 Mark-III correlators, two in the United States, one in Germany and one in Japan. The entire Mark-III system, including both the data acquisition terminals and the correlators are currently being upgraded to the Mark-IIIA high density tape format. Because of limitations on the production of the new heads it will be 1987 before enough units are available for all of the stations and correlators. To then immediately replace the Mark-IIIA with the VLBA system would be difficult to justify. Compatibility is too valuable to be sacrificed, and we strongly recommend that the VLBA not isolate itself from the rest of the international community by adopting incompatible instrumentation.