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Wireless Access Methods and Physical Layer Specifications

Title: Enhancement of Multiple Access for DFWMAC

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Abstract

Due to the problems of DFWMAC to apply CSMA/CA , we proposed a way to enhance the multiple access protocol of DFWMAC without changing its structure and introducing implementation difficulty. The enhancement is based on the randomly address polling to greatly increase the efficiency of MAC.

Introduction

In the November 1993 meeting, MAC group decided to pick DFWMAC as the direction to develop the foundation MAC protocol. The proposed DFWMAC applies CSMA/CA (carrier sense multiple access with collision avoidance) with acknowledgement as the uplink multiple access [1]. However, the fittness of CSMA in wireless LANs has been doubtful in the past IEEE 802 efforts and even in the November meeting. This contribution would like to first discuss the hidden terminal problem for CSMA then propose an enhanced protocol based on the (G)RAP for the multiple access of DFWMAC.

Problems for Multiple Access of DFWMAC

As pointed out in [4], nonpersistent CSMA that is most suitable for wireless networks suffers from severe performance degradation due to cell interference and especially hidden terminals. Hidden terminals are very likely to exist in the environments where wireless LANs are operating due to unpredictable channel statistics. When a mobile node (say A) intends to transmit its packet and another mobile node (say B) is also in transmission to the same base station but A can not sense B's transmission, this results in an unavoidable collision and B is known as the hidden terminal of A. In the analytical results of [4], the hidden terminal has less severe affect due to the sttochstic modeling. A hidden terminal like B remains a hidden terminal with probability P_H. A troublesome hidden terminal will not exist for a while. However, as the operation experience of existing wireless LANs products, a receiver can almost always (surely in terms of short term definition) hear another transmitter if it can hear. If it can not hear another, it almost always (again in terms of short term definition) can not hear. This implies that **once we have a hidden terminal, then we have one for a while** Please note that the packet transmission time in wireless LANs is around the range (1-4K bits) / (1-2M bps) = 1-4 msec while the channel will not change a lot in such a short time for most of the cases. What we can learn from above is

(1) The hidden terminal analysis of nonpersistent CSMA with multicell coverage in [4], though reduces the effectness to around 50% of the traditional analysis, is still an opmisitic result.
(2) If we want to increase the sensing time to reduce the hidden terminal probability, it is basically useless unless we sense for several packet transmission time, a great loss for channel efficiency.

There are further concerns for the CSMA/CA in wireless networks.

(1) This is a well known unstable multiple access protocol whose delay has a huge "jump" near the peak throughput. It is essentially not feasible for any time bounded service unless the offered traffic load is light to result in rather limited throuput (and thus channel utilization).
(2) In many implementations such as DFWMAC [1], synchronization among all nodes and base stations to maintian a universal clock is used though not needed in general. This again implies a nontrivial overhead accounted to the throughput performance.

Proposed Modification of the Multiple Access in DFWMAC

Under many unfavorable constraints of CSMA, DFWMAC may have done the best possible way trying to make CSMA work in wireless networks operating in the harsh fading channels. However, the best way to improve the detailed defined DFWMAC may be to pick up another effective multiple access protocol which can fit in the structure of DFWMAC. A detailed review on multiple access protocols possibly to be used in wireless LANs has been provided in [5]. Considering a multicell coverage and fading operation channels, we need a multiple access protocol enjoies centralized control and the ease of decentralized access. ALOHA family of protocols (including CSMA), polling, and token passing, are far from our best possible choice. A new multiple access protoocl, (group) randomly addresed polling, may best suit what we need. The performance of (G)RAP has been carefully evaluated [2,3] and shown to be effective. The detailed description of (G)RAP can be found in [6,7]. We briefly summarize the procedure of RAP as follows.

Step 1: The base station broadcasts a [READY] to request transmission. This step is the same as [RTS] in the DFWMAC except [READY] can be implicit.
Step 2: All ready uses transmit their random addresses generated by themselves to the base station. This step is similar to the "listening" stage of DFWMAC.
Step 3: With a special device though trivial in hardware design, the base station can simultaneously detect asynchronous orthogonal signaling to learn the random addresses. This step is similar to "collision avoidance" of the DFWMAC.
Step 4: The base station polls according to the random addresses. This step is similar to the [CTS].

The acknowledge scheme can still use the one as DFWMAC. The primary concern is the special device to detect the multiple random addresses (random address detector) at the base station. We demonstrate a simple realization and its simulations based on *SPW* shown in Figures 1-4. Figure 1 is the blcok diagram of simulations. The multiple address detector (MAD) is composed of bandpass fileter (Butterworth 4th order), hard limiter, and an energy detector for each branch. Figure 2 shows the case that 4 simultaneous transmissions and all 4 can be reliably detected. Figure 3 shows the case of imperfect power control (or near-far case) with one transmission with 7dB less power. The MAD works perfectly well. Figure 4 shows the case with 2 normal transmissions and one weaker transmission (7dB less). Again, MAD works fine. All the simulations is based on 10 dB SNR. A reliable detection requires 79 symbols with trivial false alarm probability. If we can tolerate higher false alarm probability, or better signal design, or better hardware design, this number is expected to be further reduced. However, from our analysis of RAP, this difference has almost no observable effects on performance.

Tradeoffs

The advantages to adopt (G)RAP to DFWMAC are clear:

(1) No hidden terminal problem and near-far problem: All procesures are done centrally and the MAD can tolerate imperfect power control (or equivalently near-far situation) with around 20 dB dynamic range.
(2) Performance: Such an enhancement with the price of a rather trivial hardware can deliver much better throughput and delay performance while the DFWMAC structure and operation remain unchanged. Please note that (G)RAP can deal with multiple requests while CSMA/CA in the DFWMAC can only deal with one transmission in a [RTS]-[CTS] cycle.
(3) Stability: GRAP can deliver a very stablized version of multiple access to meet time-bounded services.
(4) Implications on system issues: If we can adopt the concepts of (G)RAP into DFWMAC, it can alleviate many system requirements in the DFWMAC such as maintaning a universal clock among base stations and mobile nodes, power control, scanning, etc.

The primary disadvantage of this proposed enhancement is that it is a new concept.

Conclusions

The contribution has proposed an enhancement of the multiple access part in the DFWMAC to overcome the main doubt of DFWMAC and provide a lot of advantages. In such a way, a more desirable MAC for wireless LANs is resulted.

References

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[3] -------, "Group Randomly Addressed Polling for Wireless Data Networks", to appear in the *Proc. IEEE International Conference on Communications,* New Orleans, 1994.

[4] W.L. Huang, K.C. Chen, "Performance of Nonpersistent CSMA with Overlapped Cell-Coverage and Hidden Terminals in Wireless Networks", submitted for publication.

[5] K.C. Chen, "On the Design of Medium Access Control Protocol for Wireless Local Area Networks", submitted for publication.

[6] K.C. Chen, "GRAP - A Proposed Medium Access Control Protocol for Wireless LANs", *IEEE P802.11/92-107.*

[7] K.C. Chen, C.P. Jeremy Tzeng, "More on the GRAP", *IEEE P802.11/93-39.*

Figure 1

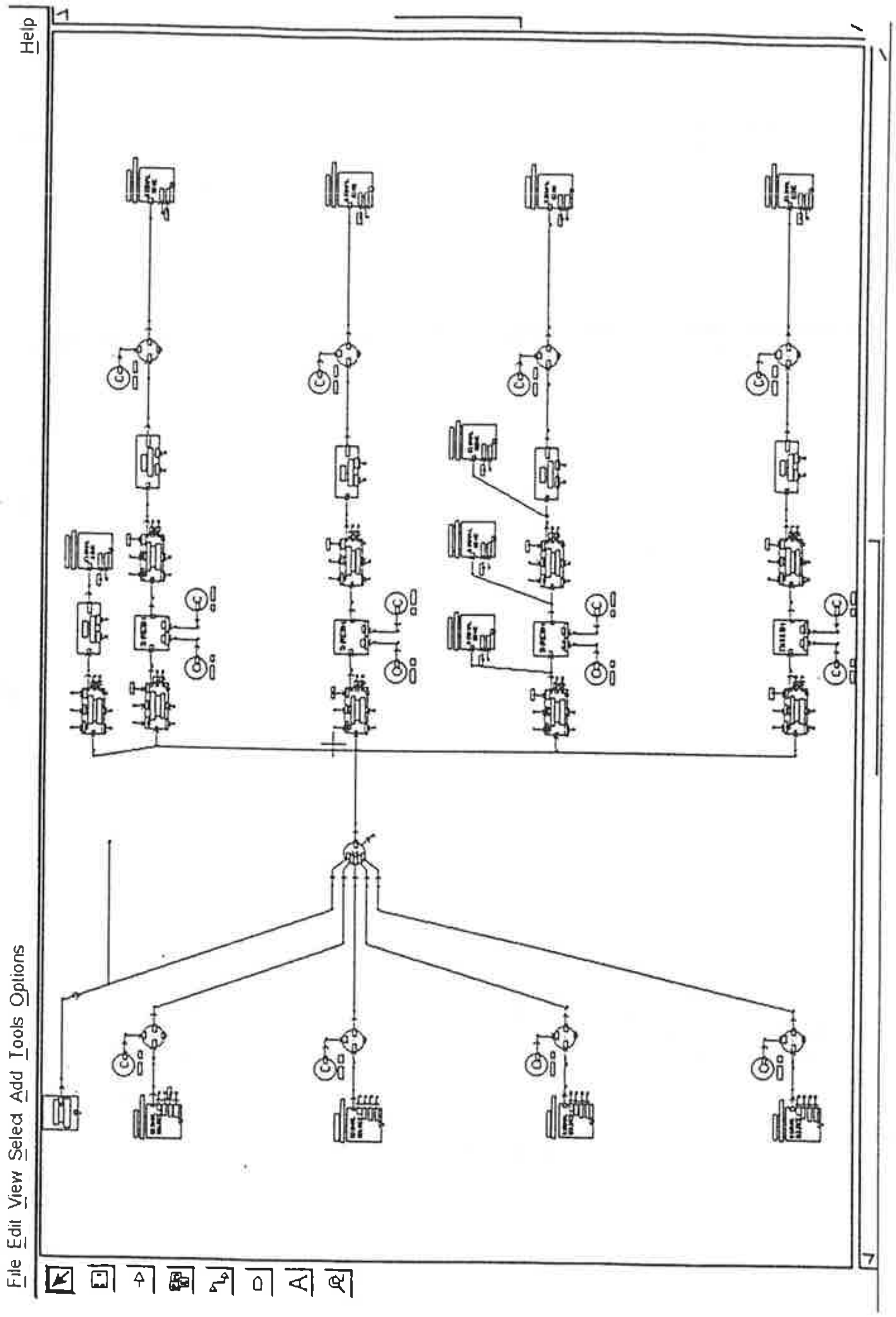
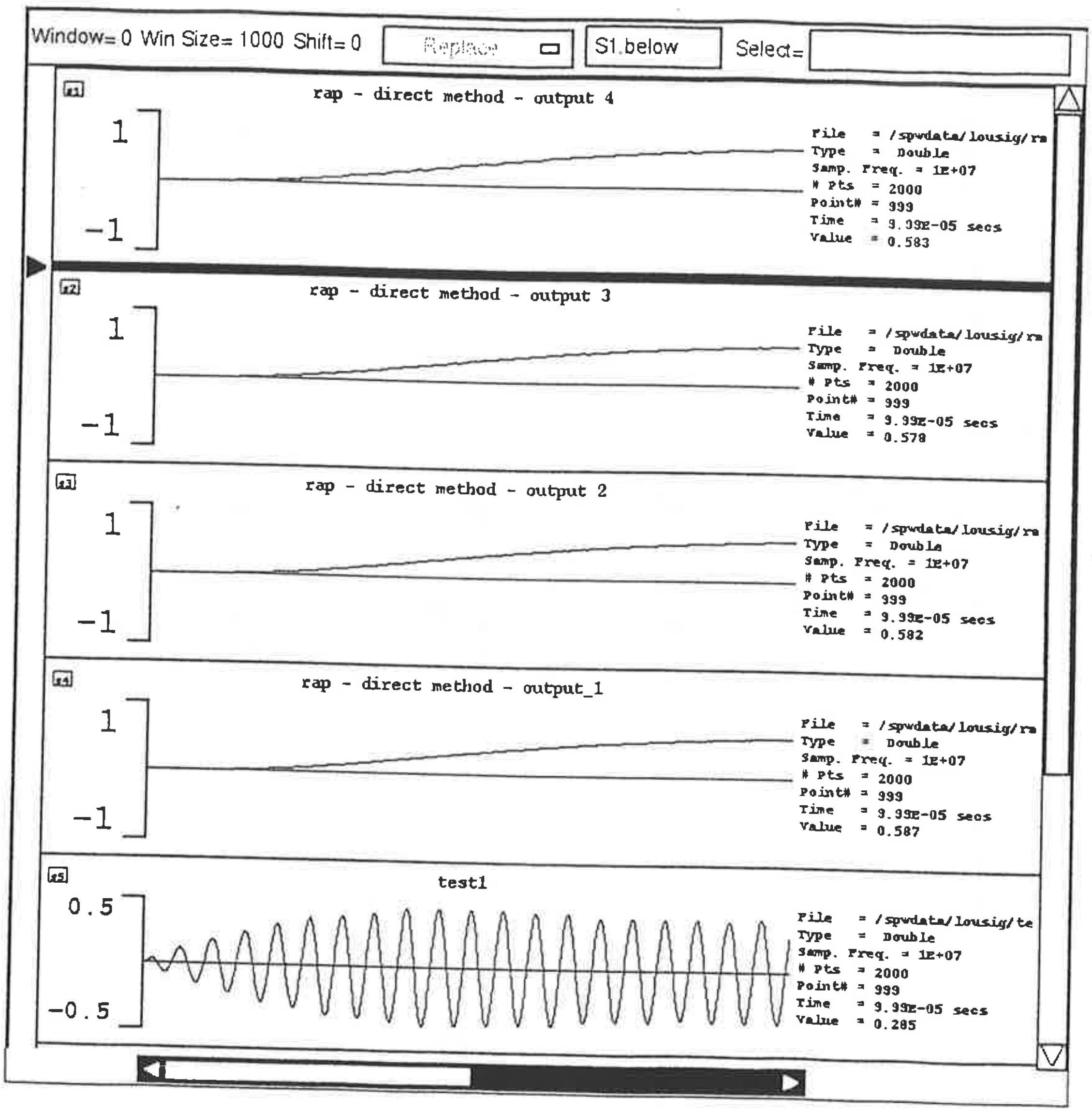


Figure 2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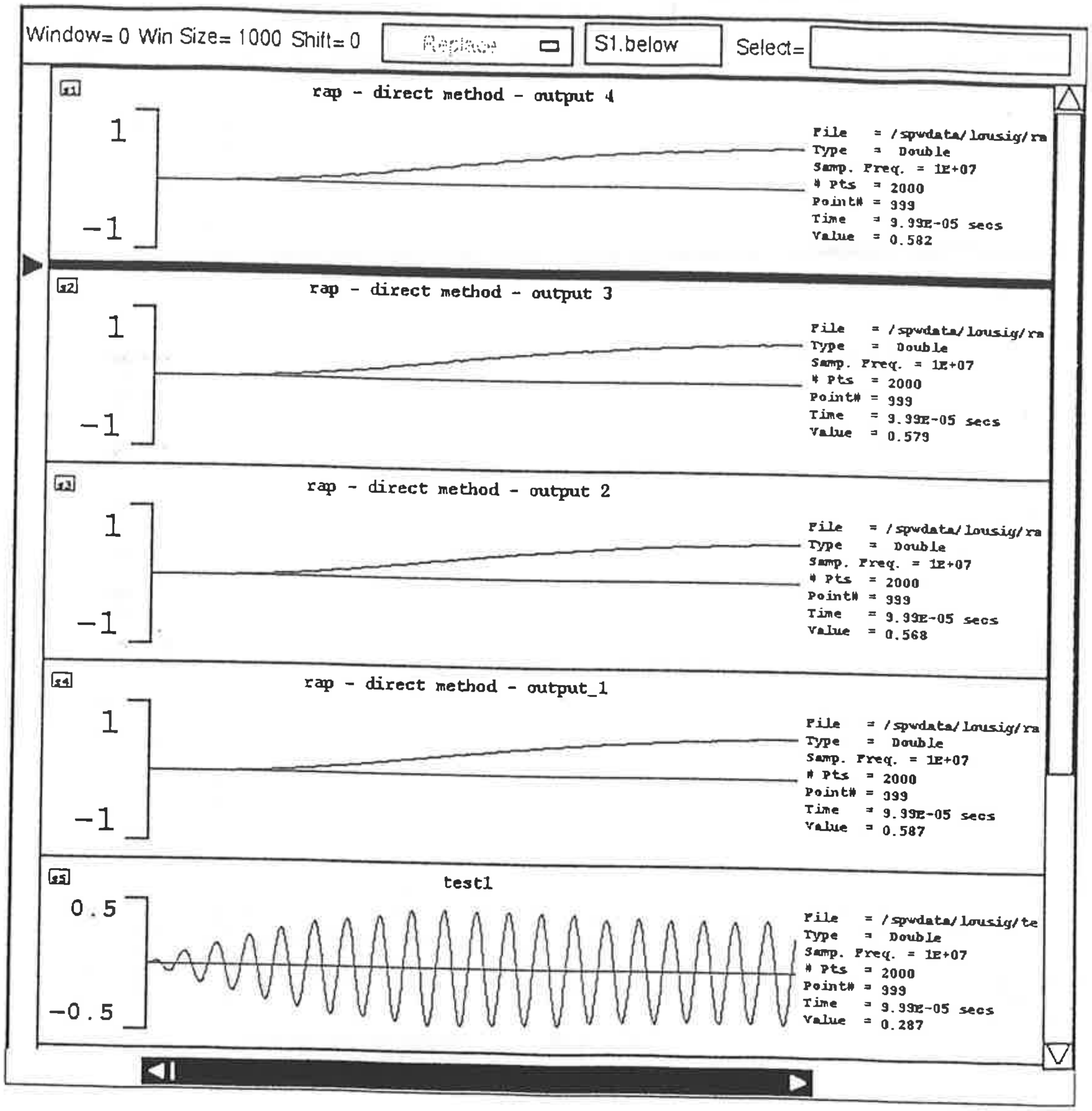
S1.below
Select=
rap - direct method - output 4
File = /spwdata/lousig/ra
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.583
rap - direct method - output 3
Value = 0.578
rap - direct method - output 2
Value = 0.582
rap - direct method - output_1
Value = 0.587
test1
File = /spwdata/lousig/te
Value = 0.285

Figure 3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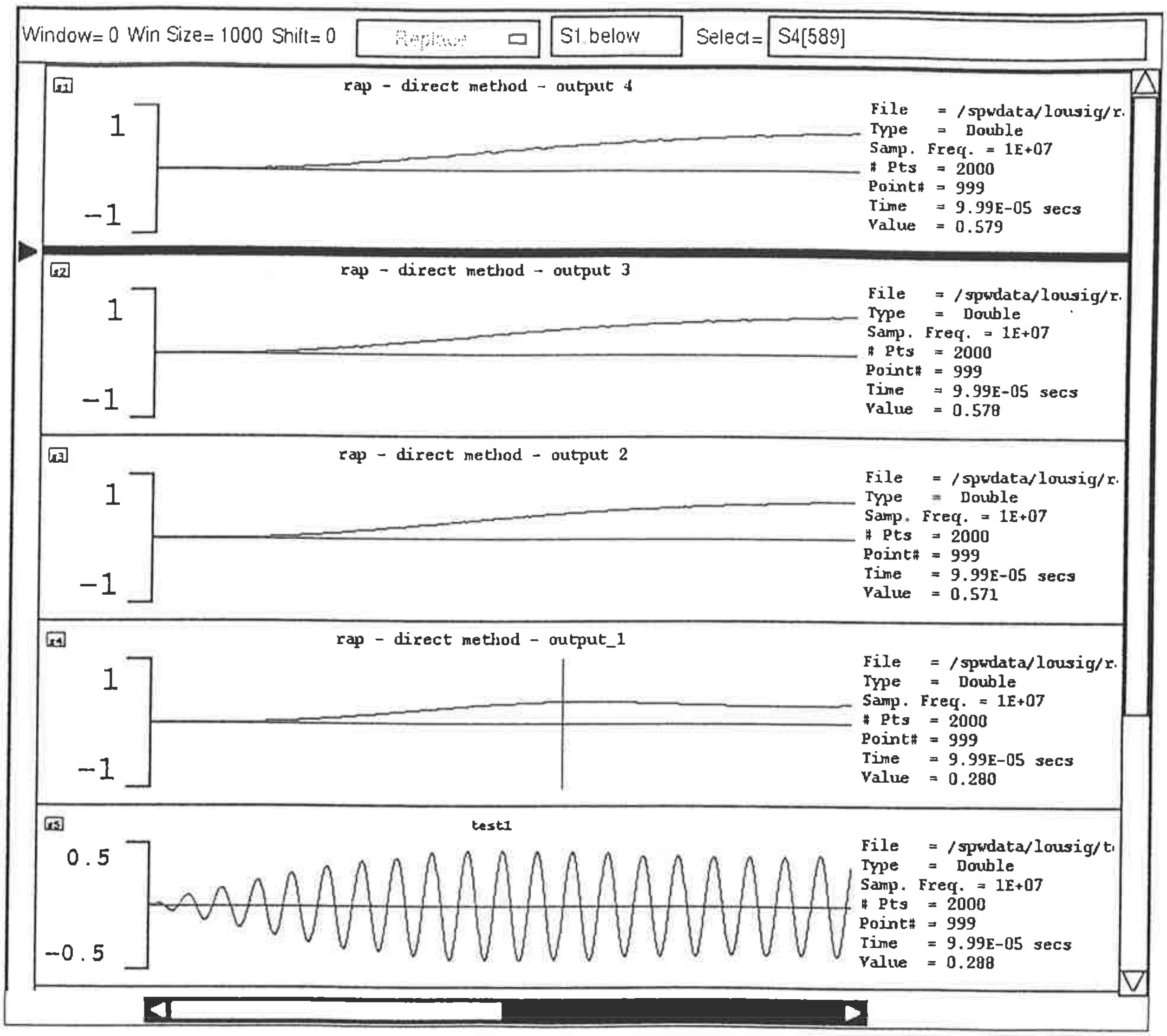
Replace
S1.below
Select=
rap - direct method - output 4
1
-1
File = /spwdata/lousig/ra
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.582
rap - direct method - output 3
1
-1
File = /spwdata/lousig/ra
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.579
rap - direct method - output 2
1
-1
File = /spwdata/lousig/ra
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.568
rap - direct method - output_1
1
-1
File = /spwdata/lousig/ra
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.587
test1
0.5
-0.5
File = /spwdata/lousig/te
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.287

Figure 4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S1 below
Select=
S4[589]
rap - direct method - output 4
1
-1
File = /spwdata/lousig/r
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.579
rap - direct method - output 3
1
-1
File = /spwdata/lousig/r
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.578
rap - direct method - output 2
1
-1
File = /spwdata/lousig/r
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.571
rap - direct method - output_1
1
-1
File = /spwdata/lousig/r
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.280
test1
0.5
-0.5
File = /spwdata/lousig/t
Type = Double
Samp. Freq. = 1E+07
Pts = 2000
Point# = 999
Time = 9.99E-05 secs
Value = 0.288