组会报告

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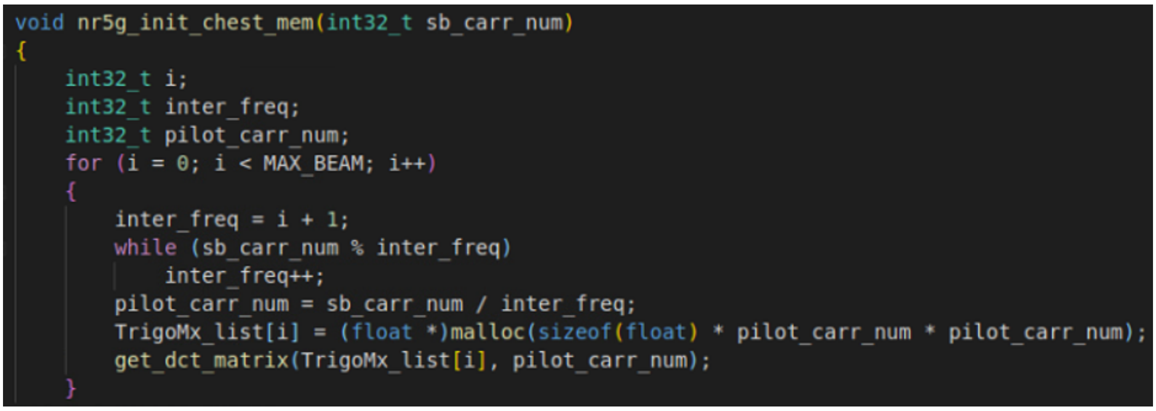
1 工作内容

1. 提高信道估计和信号检测部分吞吐量；
2. 根据当前系统性能设计新的多线程系统；
3. 根据测试需求改写数据采集程序。

2 提高信道估计和信号检测部分吞吐量

2.1 优化要点

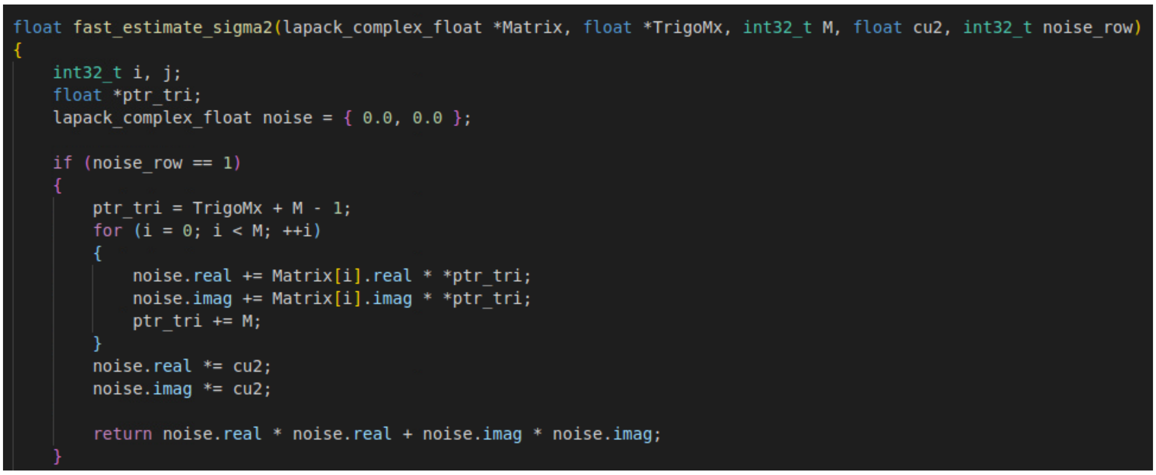
2.1.1 预先生成 DCT 矩阵



```
void nr5g_init_chest_mem(int32_t sb_carr_num)
{
    int32_t i;
    int32_t inter_freq;
    int32_t pilot_carr_num;
    for (i = 0; i < MAX_BEAM; i++)
    {
        inter_freq = i + 1;
        while (sb_carr_num % inter_freq)
            inter_freq++;
        pilot_carr_num = sb_carr_num / inter_freq;
        TrigoMx_list[i] = (float *)malloc(sizeof(float) * pilot_carr_num * pilot_carr_num);
        get_dct_matrix(TrigoMx_list[i], pilot_carr_num);
    }
```

图 1: 信道估计初始化部分

2.1.2 估计噪声时不做完整的 DCT 变换代码



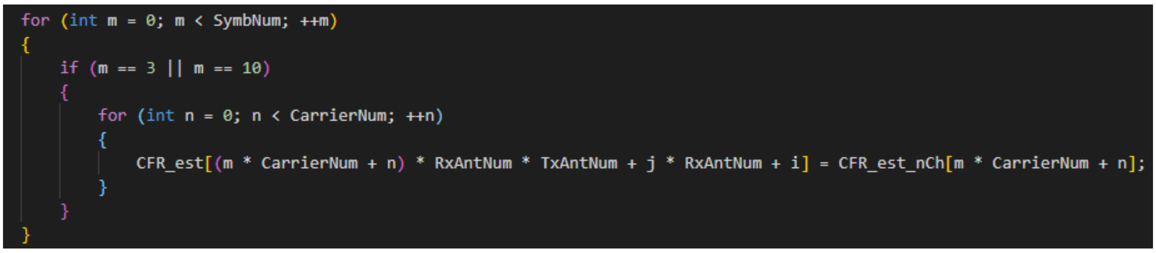
```
float fast_estimate_sigma2(lapack_complex_float *Matrix, float *TrigoMx, int32_t M, float cu2, int32_t noise_row)
{
    int32_t i, j;
    float *ptr_tri;
    lapack_complex_float noise = { 0.0, 0.0 };

    if (noise_row == 1)
    {
        ptr_tri = TrigoMx + M - 1;
        for (i = 0; i < M; ++i)
        {
            noise.real += Matrix[i].real * *ptr_tri;
            noise.imag += Matrix[i].imag * *ptr_tri;
            ptr_tri += M;
        }
        noise.real *= cu2;
        noise.imag *= cu2;

        return noise.real * noise.real + noise.imag * noise.imag;
    }
```

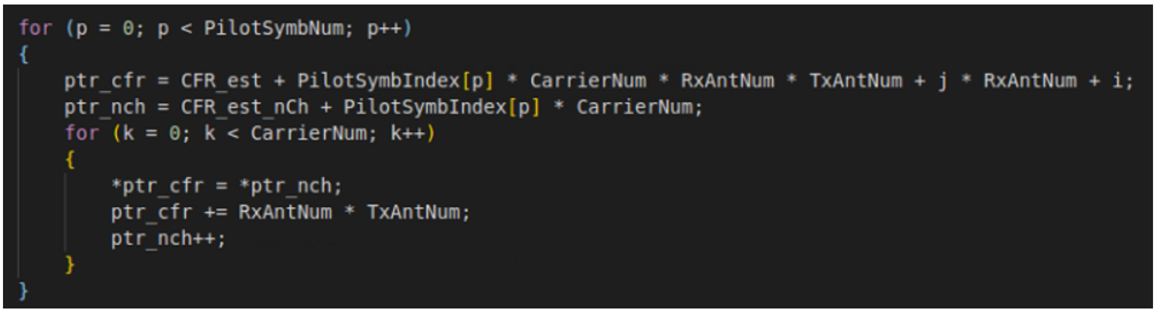
图 2: 估计噪声部分代码

2.1.3 指针移位寻址代替地址计算



```c
for (int m = 0; m < SymbNum; ++m)
{
    if (m == 3 || m == 10)
    {
        for (int n = 0; n < CarrierNum; ++n)
        {
            CFR_est[(m * CarrierNum + n) * RxAntNum * TxAntNum + j * RxAntNum + i] = CFR_est_nCh[m * CarrierNum + n];
        }
    }
}
```

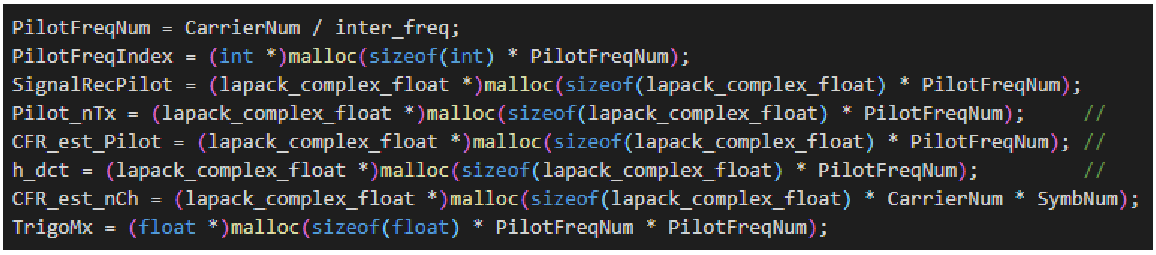
图 3: 原代码寻址部分



```c
for (p = 0; p < PilotSymbNum; p++)
{
    ptr_cfr = CFR_est + PilotSymbIndex[p] * CarrierNum * RxAntNum * TxAntNum + j * RxAntNum + i;
    ptr_nch = CFR_est_nCh + PilotSymbIndex[p] * CarrierNum;
    for (k = 0; k < CarrierNum; k++)
    {
        *ptr_cfr = *ptr_nch;
        ptr_cfr += RxAntNum * TxAntNum;
        ptr_nch++;
    }
}
```

图 4: 现代码寻址部分

2.1.4 去除不必要的内部空间开辟

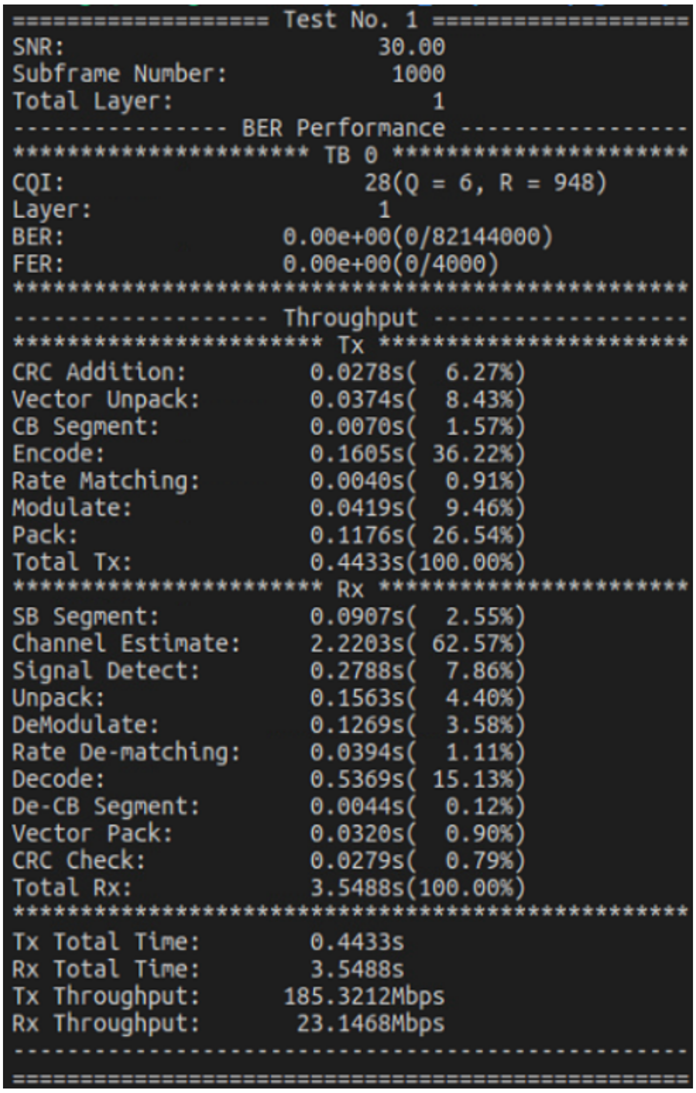


```c
PilotFreqNum = CarrierNum / inter_freq;
PilotFreqIndex = (int *)malloc(sizeof(int) * PilotFreqNum);
SignalRecPilot = (lapack_complex_float *)malloc(sizeof(lapack_complex_float) * PilotFreqNum);
Pilot_nTx = (lapack_complex_float *)malloc(sizeof(lapack_complex_float) * PilotFreqNum);     //
CFR_est_Pilot = (lapack_complex_float *)malloc(sizeof(lapack_complex_float) * PilotFreqNum); //
h_dct = (lapack_complex_float *)malloc(sizeof(lapack_complex_float) * PilotFreqNum);         //
CFR_est_nCh = (lapack_complex_float *)malloc(sizeof(lapack_complex_float) * CarrierNum * SymbNum);
TrigoMx = (float *)malloc(sizeof(float) * PilotFreqNum * PilotFreqNum);
```

图 5: 原代码中开辟空间部分

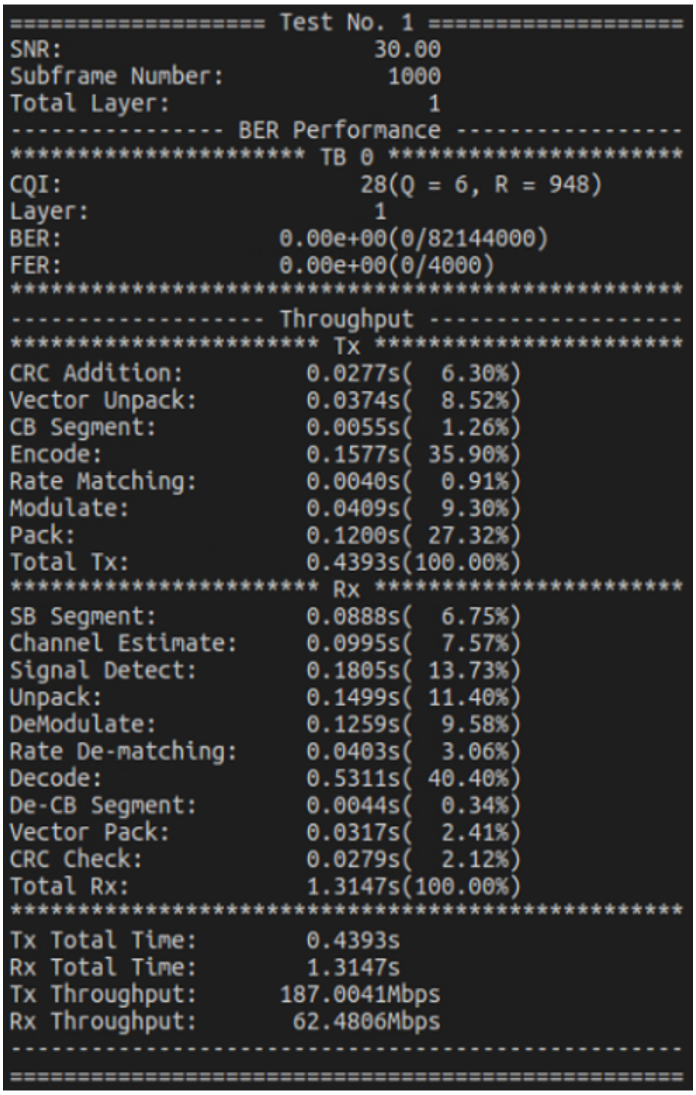
2.2 优化成果

2.2.1 单流系统性能对比



```
=================== Test No. 1 ===================
SNR:                          30.00
Subframe Number:               1000
Total Layer:                      1
---------------- BER Performance ----------------
********************** TB 0 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                          1
BER:                  0.00e+00(0/82144000)
FER:                  0.00e+00(0/4000)
**************************************************
------------------- Throughput -------------------
*********************** Tx ***********************
CRC Addition:           0.0278s(  6.27%)
Vector Unpack:          0.0374s(  8.43%)
CB Segment:             0.0070s(  1.57%)
Encode:                 0.1605s( 36.22%)
Rate Matching:          0.0040s(  0.91%)
Modulate:               0.0419s(  9.46%)
Pack:                   0.1176s( 26.54%)
Total Tx:               0.4433s(100.00%)
*********************** Rx ***********************
SB Segment:             0.0907s(  2.55%)
Channel Estimate:       2.2203s( 62.57%)
Signal Detect:          0.2788s(  7.86%)
Unpack:                 0.1563s(  4.40%)
DeModulate:             0.1269s(  3.58%)
Rate De-matching:       0.0394s(  1.11%)
Decode:                 0.5369s( 15.13%)
De-CB Segment:          0.0044s(  0.12%)
Vector Pack:            0.0320s(  0.90%)
CRC Check:              0.0279s(  0.79%)
Total Rx:               3.5488s(100.00%)
**************************************************
Tx Total Time:          0.4433s
Rx Total Time:          3.5488s
Tx Throughput:        185.3212Mbps
Rx Throughput:         23.1468Mbps
--------------------------------------------------
==================================================
```

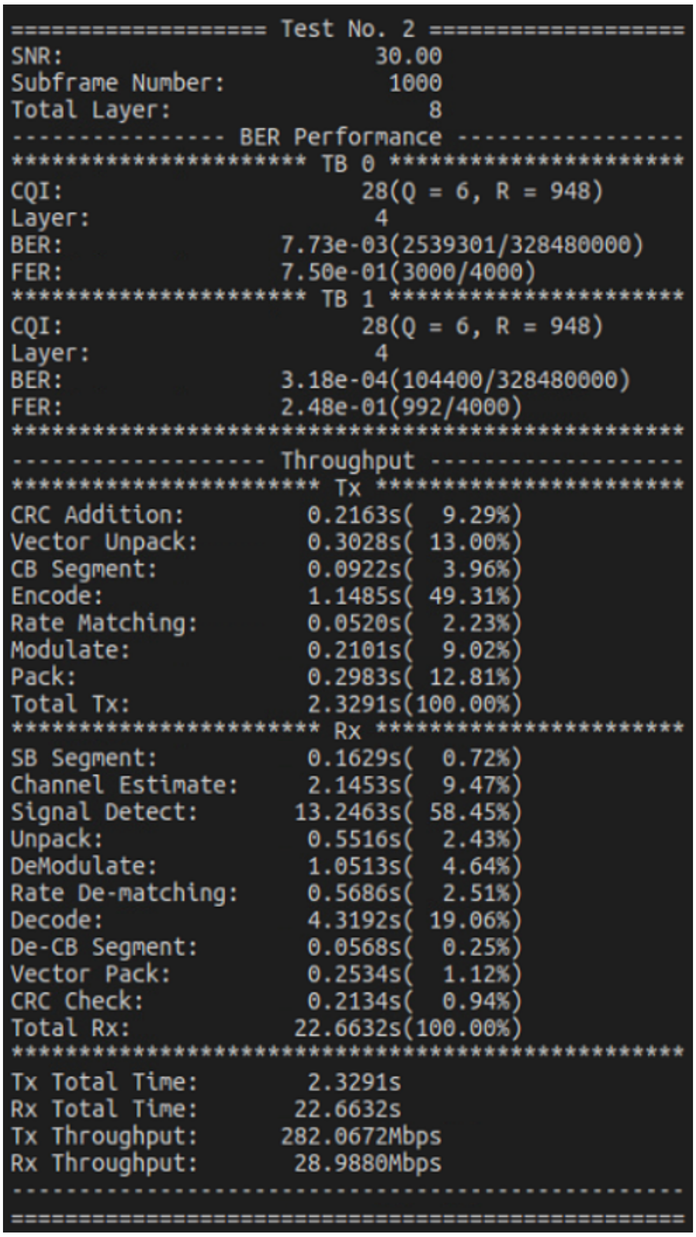
图 6: 优化前



```
=================== Test No. 1 ===================
SNR:                          30.00
Subframe Number:               1000
Total Layer:                      1
---------------- BER Performance ----------------
********************** TB 0 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                          1
BER:                  0.00e+00(0/82144000)
FER:                  0.00e+00(0/4000)
**************************************************
------------------- Throughput -------------------
*********************** Tx ***********************
CRC Addition:           0.0277s(  6.30%)
Vector Unpack:          0.0374s(  8.52%)
CB Segment:             0.0055s(  1.26%)
Encode:                 0.1577s( 35.90%)
Rate Matching:          0.0040s(  0.91%)
Modulate:               0.0409s(  9.30%)
Pack:                   0.1200s( 27.32%)
Total Tx:               0.4393s(100.00%)
*********************** Rx ***********************
SB Segment:             0.0888s(  6.75%)
Channel Estimate:       0.0995s(  7.57%)
Signal Detect:          0.1805s( 13.73%)
Unpack:                 0.1499s( 11.40%)
DeModulate:             0.1259s(  9.58%)
Rate De-matching:       0.0403s(  3.06%)
Decode:                 0.5311s( 40.40%)
De-CB Segment:          0.0044s(  0.34%)
Vector Pack:            0.0317s(  2.41%)
CRC Check:              0.0279s(  2.12%)
Total Rx:               1.3147s(100.00%)
**************************************************
Tx Total Time:          0.4393s
Rx Total Time:          1.3147s
Tx Throughput:        187.0041Mbps
Rx Throughput:         62.4806Mbps
--------------------------------------------------
==================================================
```

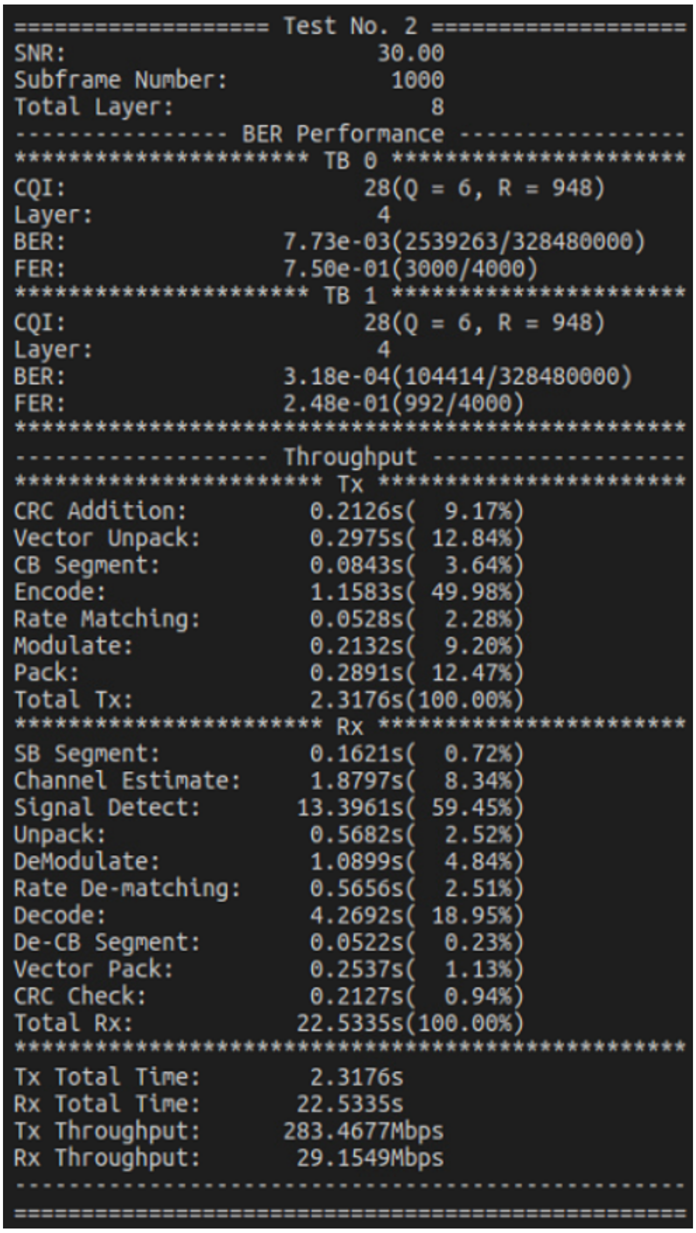
图 7: 优化后

2.2.2 八流系统性能对比



```
=================== Test No. 2 ===================
SNR:                         30.00
Subframe Number:              1000
Total Layer:                     8
---------------- BER Performance ----------------
********************** TB 0 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                         4
BER:                  7.73e-03(2539301/328480000)
FER:                  7.50e-01(3000/4000)
********************** TB 1 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                         4
BER:                  3.18e-04(104400/328480000)
FER:                  2.48e-01(992/4000)
**************************************************
------------------- Throughput -------------------
*********************** Tx ***********************
CRC Addition:          0.2163s(  9.29%)
Vector Unpack:         0.3028s( 13.00%)
CB Segment:            0.0922s(  3.96%)
Encode:                1.1485s( 49.31%)
Rate Matching:         0.0520s(  2.23%)
Modulate:              0.2101s(  9.02%)
Pack:                  0.2983s( 12.81%)
Total Tx:              2.3291s(100.00%)
*********************** Rx ***********************
SB Segment:            0.1629s(  0.72%)
Channel Estimate:      2.1453s(  9.47%)
Signal Detect:        13.2463s( 58.45%)
Unpack:                0.5516s(  2.43%)
DeModulate:            1.0513s(  4.64%)
Rate De-matching:      0.5686s(  2.51%)
Decode:                4.3192s( 19.06%)
De-CB Segment:         0.0568s(  0.25%)
Vector Pack:           0.2534s(  1.12%)
CRC Check:             0.2134s(  0.94%)
Total Rx:             22.6632s(100.00%)
**************************************************
Tx Total Time:         2.3291s
Rx Total Time:        22.6632s
Tx Throughput:       282.0672Mbps
Rx Throughput:        28.9880Mbps
--------------------------------------------------
==================================================
```

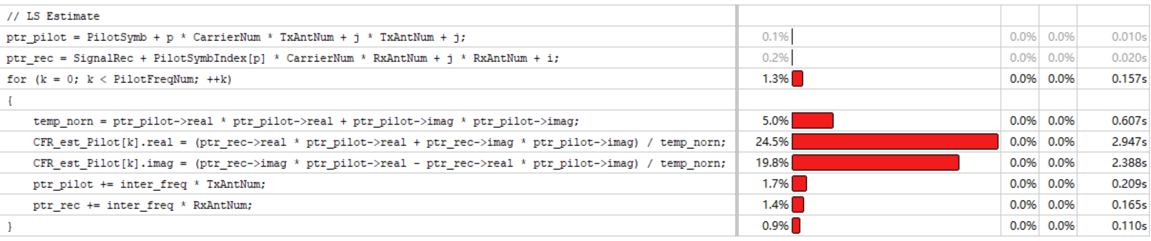
图 8: 优化前



```
=================== Test No. 2 ===================
SNR:                         30.00
Subframe Number:              1000
Total Layer:                     8
---------------- BER Performance ----------------
********************** TB 0 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                         4
BER:                  7.73e-03(2539263/328480000)
FER:                  7.50e-01(3000/4000)
********************** TB 1 **********************
CQI:                        28(Q = 6, R = 948)
Layer:                         4
BER:                  3.18e-04(104414/328480000)
FER:                  2.48e-01(992/4000)
**************************************************
------------------- Throughput -------------------
*********************** Tx ***********************
CRC Addition:          0.2126s(  9.17%)
Vector Unpack:         0.2975s( 12.84%)
CB Segment:            0.0843s(  3.64%)
Encode:                1.1583s( 49.98%)
Rate Matching:         0.0528s(  2.28%)
Modulate:              0.2132s(  9.20%)
Pack:                  0.2891s( 12.47%)
Total Tx:              2.3176s(100.00%)
*********************** Rx ***********************
SB Segment:            0.1621s(  0.72%)
Channel Estimate:      1.8797s(  8.34%)
Signal Detect:        13.3961s( 59.45%)
Unpack:                0.5682s(  2.52%)
DeModulate:            1.0899s(  4.84%)
Rate De-matching:      0.5656s(  2.51%)
Decode:                4.2692s( 18.95%)
De-CB Segment:         0.0522s(  0.23%)
Vector Pack:           0.2537s(  1.13%)
CRC Check:             0.2127s(  0.94%)
Total Rx:             22.5335s(100.00%)
**************************************************
Tx Total Time:         2.3176s
Rx Total Time:        22.5335s
Tx Throughput:       283.4677Mbps
Rx Throughput:        29.1549Mbps
--------------------------------------------------
==================================================
```

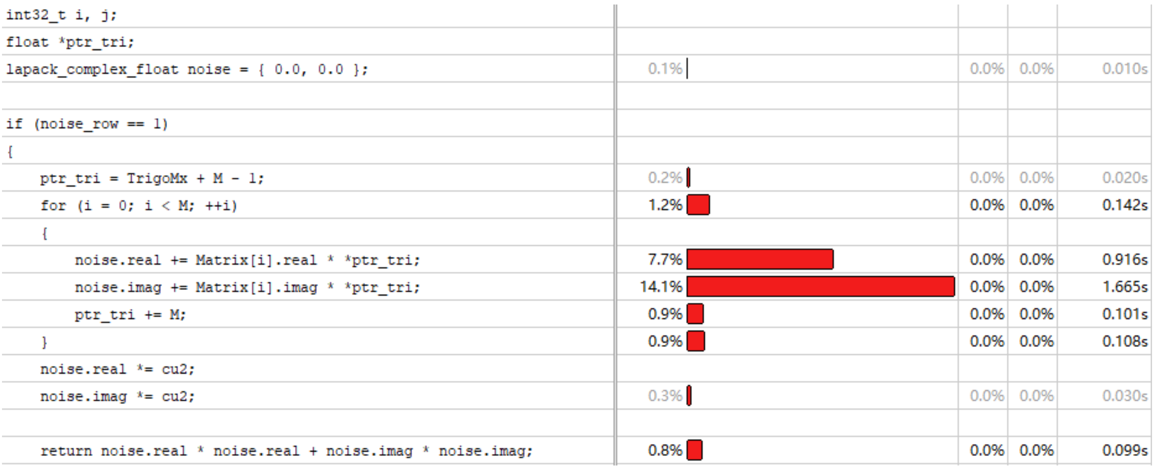
图 9: 优化后

2.3 仍存在的优化空间



```
// LS Estimate
ptr_pilot = PilotSymb + p * CarrierNum * TxAntNum + j * TxAntNum + j;                       0.1%    0.0%  0.0%  0.010s
ptr_rec = SignalRec + PilotSymbIndex[p] * CarrierNum * RxAntNum + j * RxAntNum + i;         0.2%    0.0%  0.0%  0.020s
for (k = 0; k < PilotFreqNum; ++k)                                                          1.3%    0.0%  0.0%  0.157s
{
    temp_norn = ptr_pilot->real * ptr_pilot->real + ptr_pilot->imag * ptr_pilot->imag;     5.0%    0.0%  0.0%  0.607s
    CFR_est_Pilot[k].real = (ptr_rec->real * ptr_pilot->real + ptr_rec->imag * ptr_pilot->imag) / temp_norn;   24.5%   0.0%  0.0%  2.947s
    CFR_est_Pilot[k].imag = (ptr_rec->imag * ptr_pilot->real - ptr_rec->real * ptr_pilot->imag) / temp_norn;   19.8%   0.0%  0.0%  2.388s
    ptr_pilot += inter_freq * TxAntNum;                                                     1.7%    0.0%  0.0%  0.209s
    ptr_rec += inter_freq * RxAntNum;                                                       1.4%    0.0%  0.0%  0.165s
}                                                                                           0.9%    0.0%  0.0%  0.110s
```

图 10: 信道估计复数除法部分



```
int32_t i, j;
float *ptr_tri;
lapack_complex_float noise = { 0.0, 0.0 };                          0.1%   0.0%  0.0%   0.010s

if (noise_row == 1)
{
    ptr_tri = TrigoMx + M - 1;                                      0.2%   0.0%  0.0%   0.020s
    for (i = 0; i < M; ++i)                                         1.2%   0.0%  0.0%   0.142s
    {
        noise.real += Matrix[i].real * *ptr_tri;                    7.7%   0.0%  0.0%   0.916s
        noise.imag += Matrix[i].imag * *ptr_tri;                   14.1%   0.0%  0.0%   1.665s
        ptr_tri += M;                                               0.9%   0.0%  0.0%   0.101s
    }                                                               0.9%   0.0%  0.0%   0.108s
    noise.real *= cu2;
    noise.imag *= cu2;                                              0.3%   0.0%  0.0%   0.030s

    return noise.real * noise.real + noise.imag * noise.imag;       0.8%   0.0%  0.0%   0.099s
```

图 11: 估计噪声方差部分

3 新的多线程系统

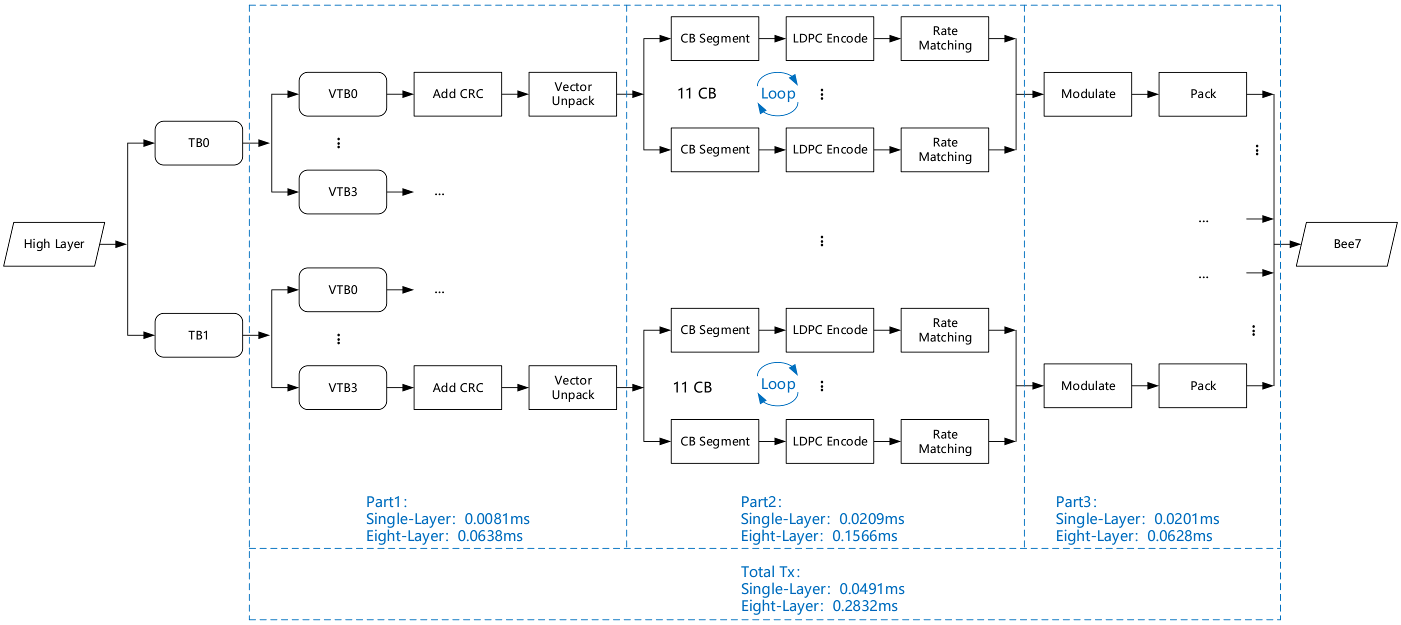


图 12: 发送端

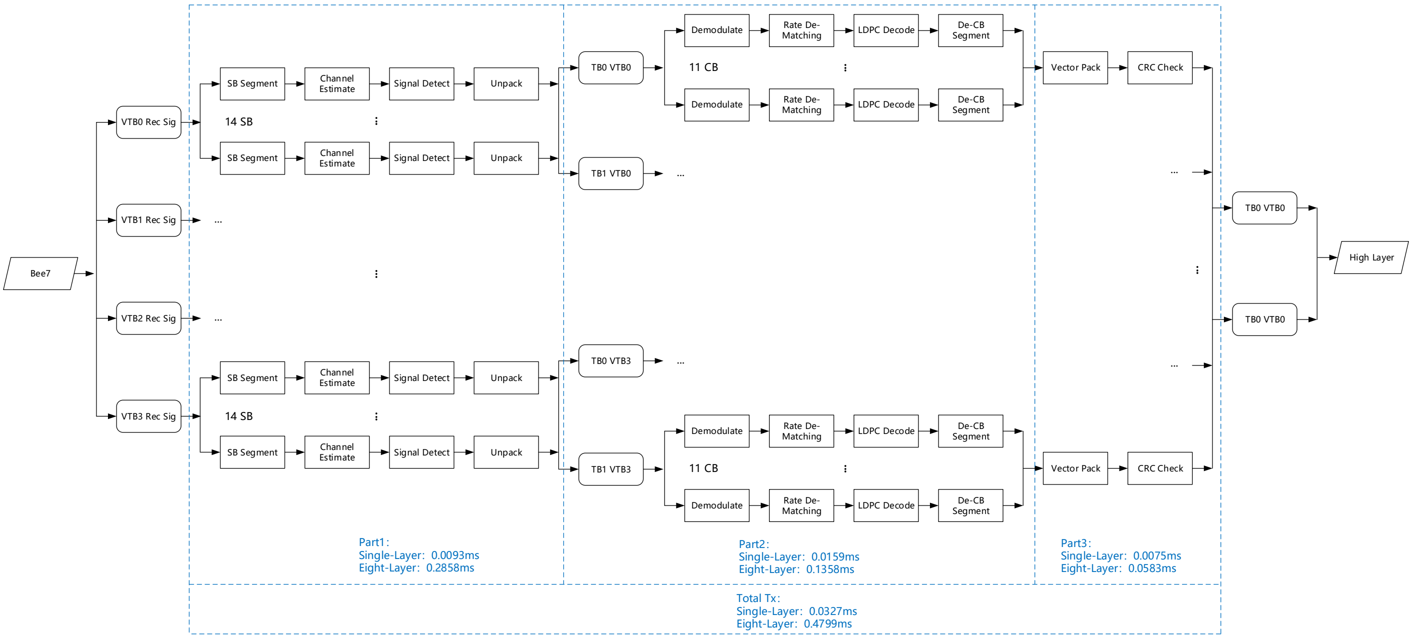


图 13: 接收端

4 修改数据采集程序

5 下阶段计划

1. 根据当前架构修改与 MAC 层对接部分；
2. 根据当前架构修改多线程系统；
3. 参与 MIMO 信道测试。