OGSR: A Low Complexity Galileo Software Receiver using Orthogonal Data and Pilot Channels

By

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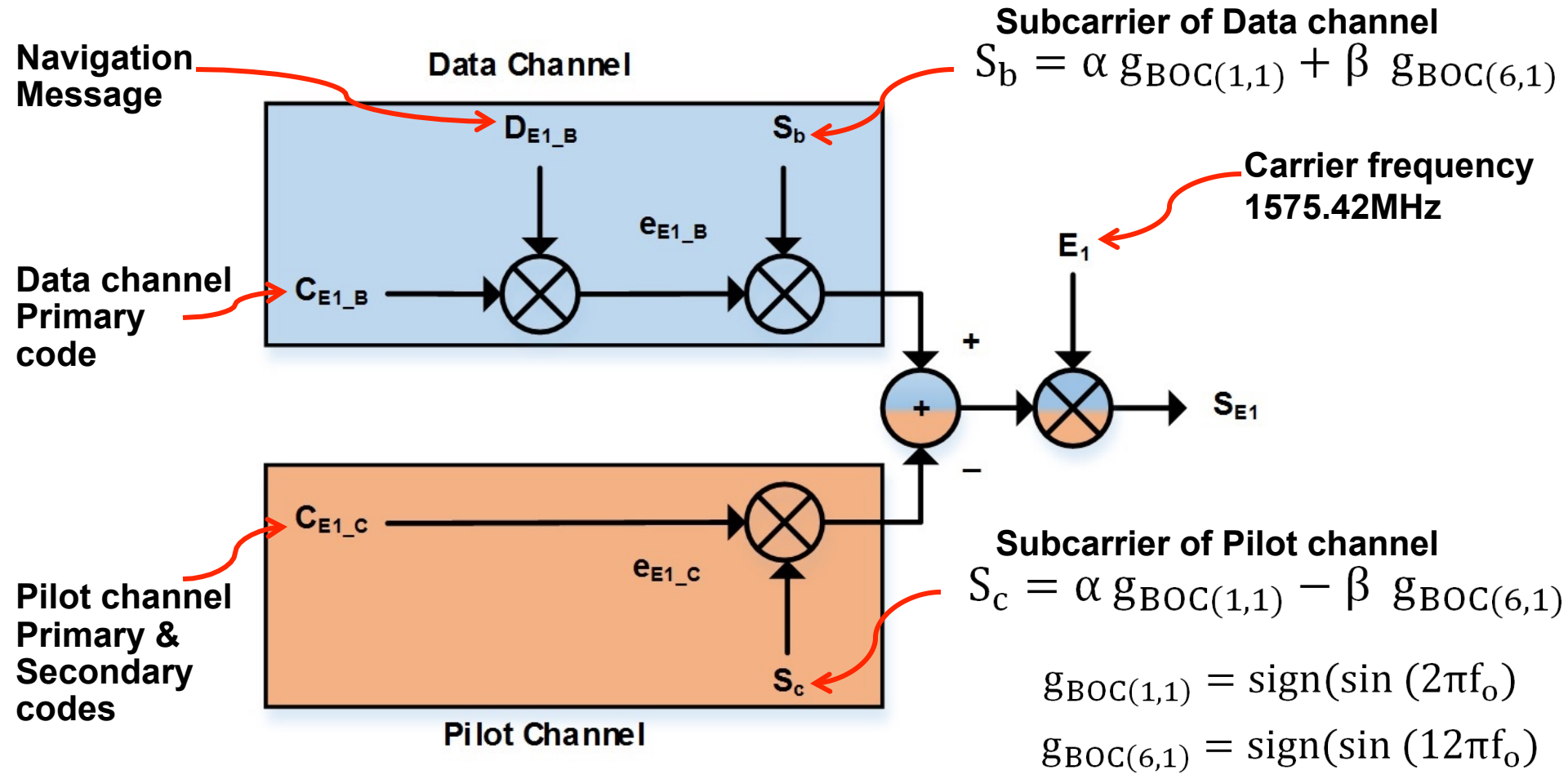
Outline

- Transmission Scheme for the Galileo-OS Signal
- Reference Methods
  - Time-Domain Implementation
  - Frequency-Domain Implementation
- Our OGSR Method
- Experimental setup
- The OGSR Analysis
- The OGSR Results
- Conclusions

Transmission Scheme for the Galileo-OS Signal



Subcarrier of Data channel

$$S_b = \alpha\, g_{BOC(1,1)} + \beta\, g_{BOC(6,1)}$$

Carrier frequency 1575.42MHz

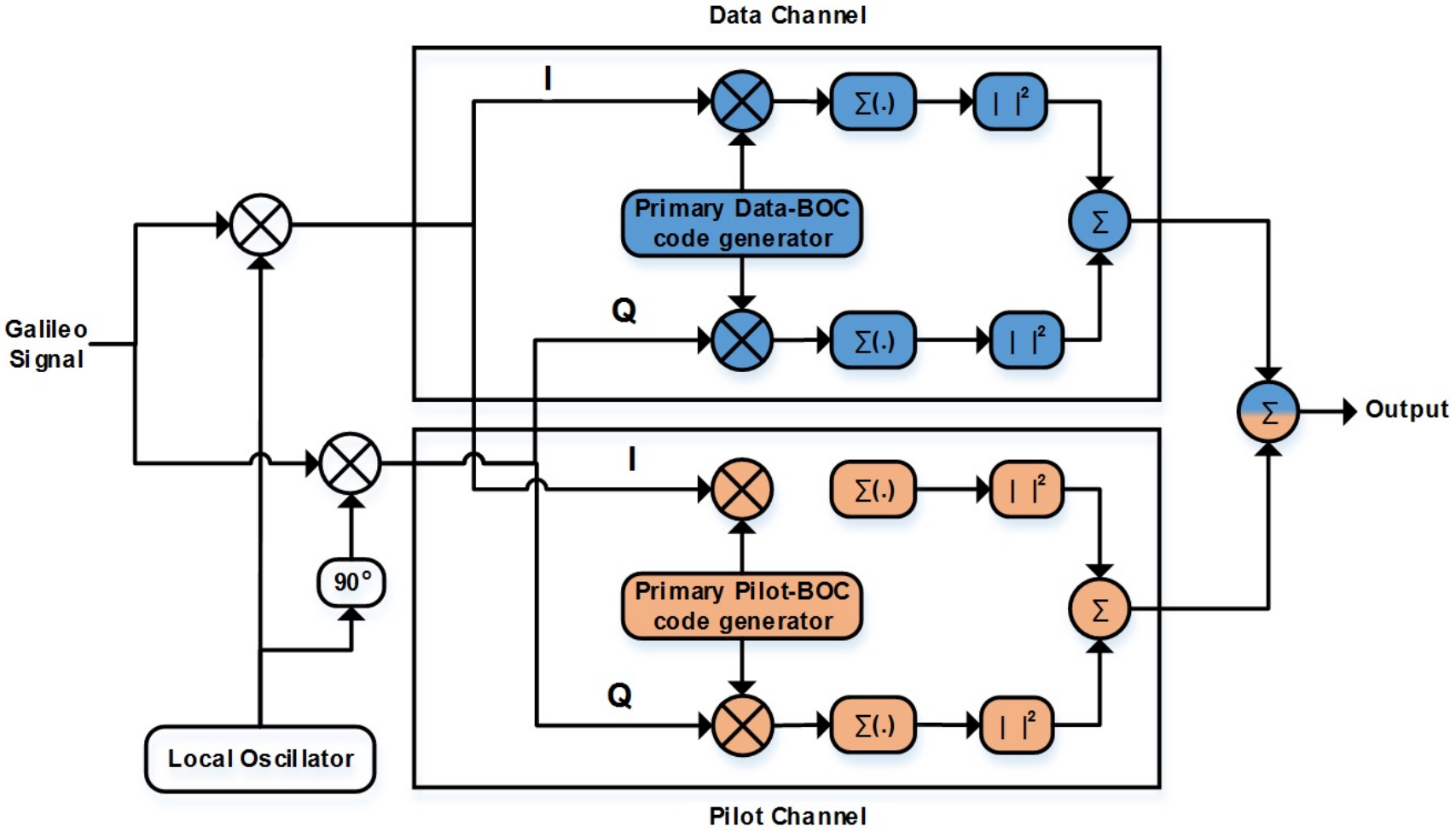
Subcarrier of Pilot channel

$$S_c = \alpha\, g_{BOC(1,1)} - \beta\, g_{BOC(6,1)}$$

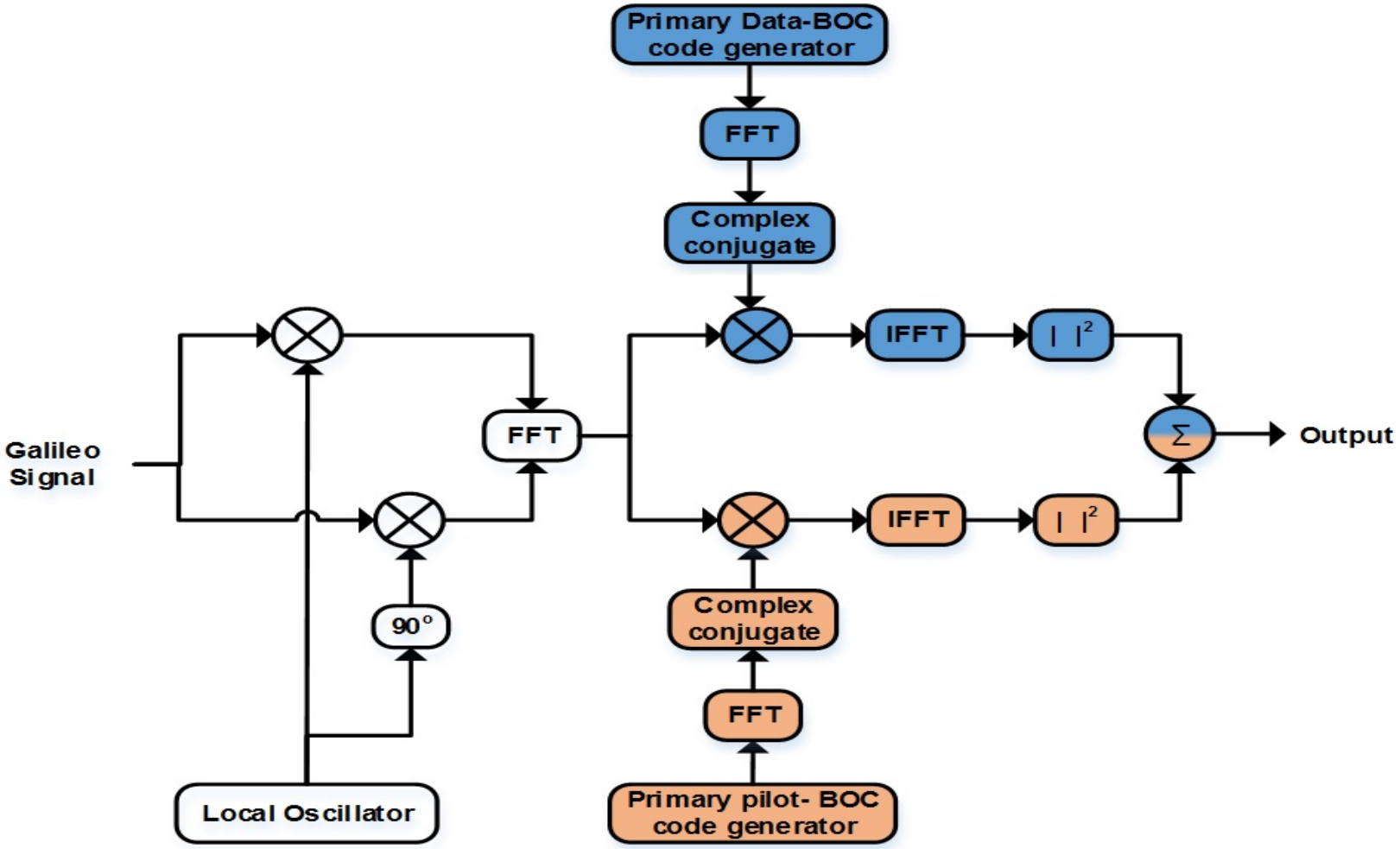
$$g_{BOC(1,1)} = \text{sign}(\sin(2\pi f_o))$$

$$g_{BOC(6,1)} = \text{sign}(\sin(12\pi f_o))$$

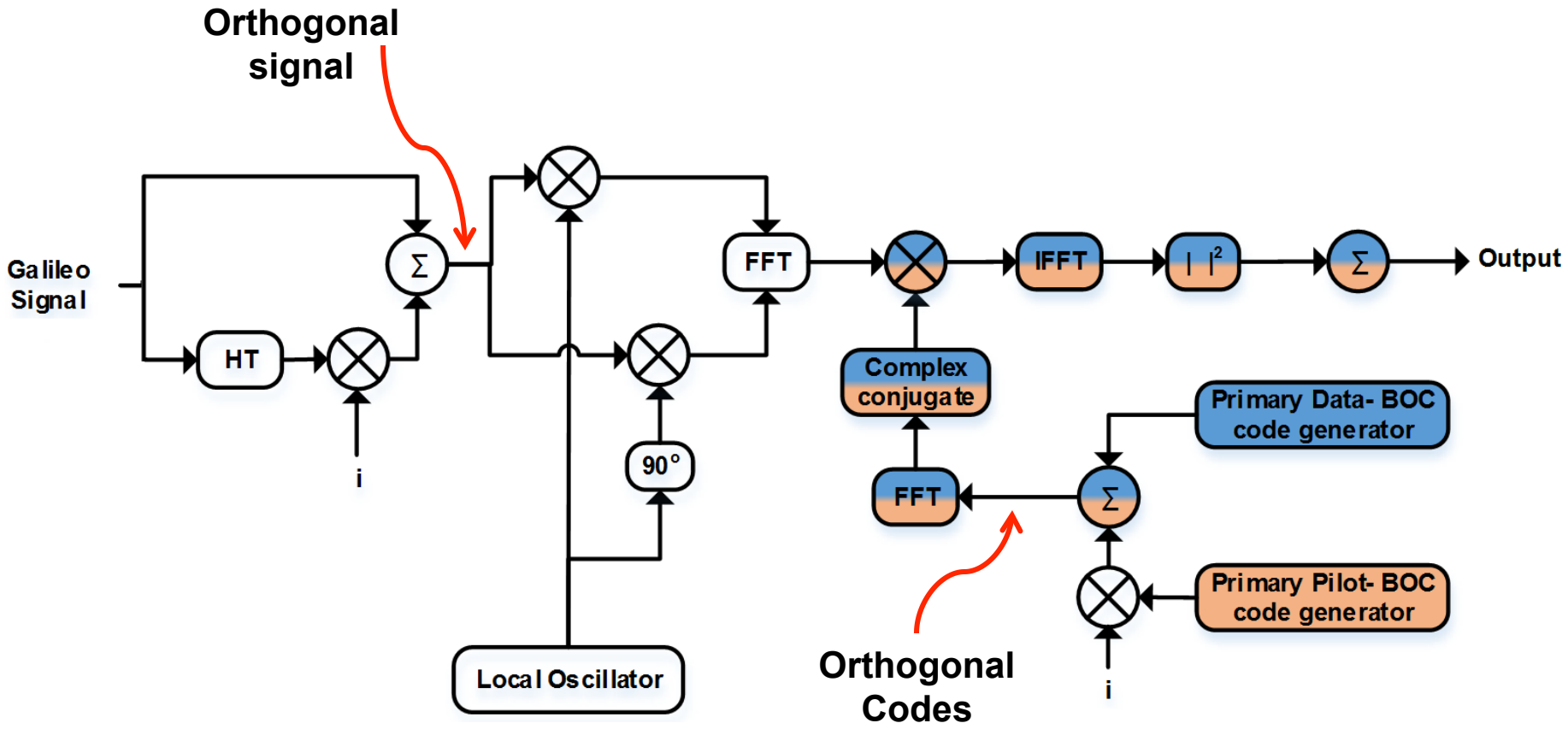
Ref1. DC acquisition method based serial search



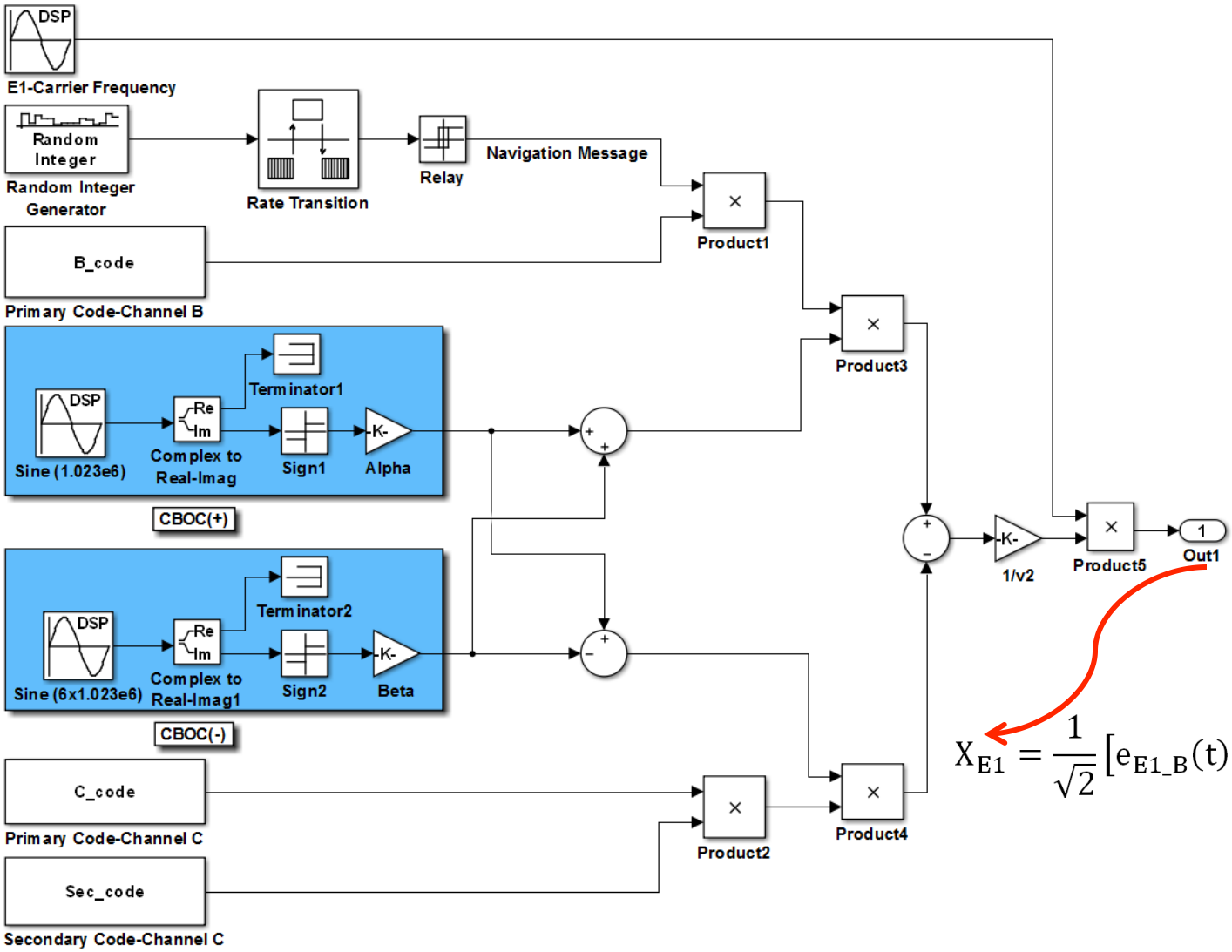
Ref2. DC acquisition method based FFT search



Our OGSR Method

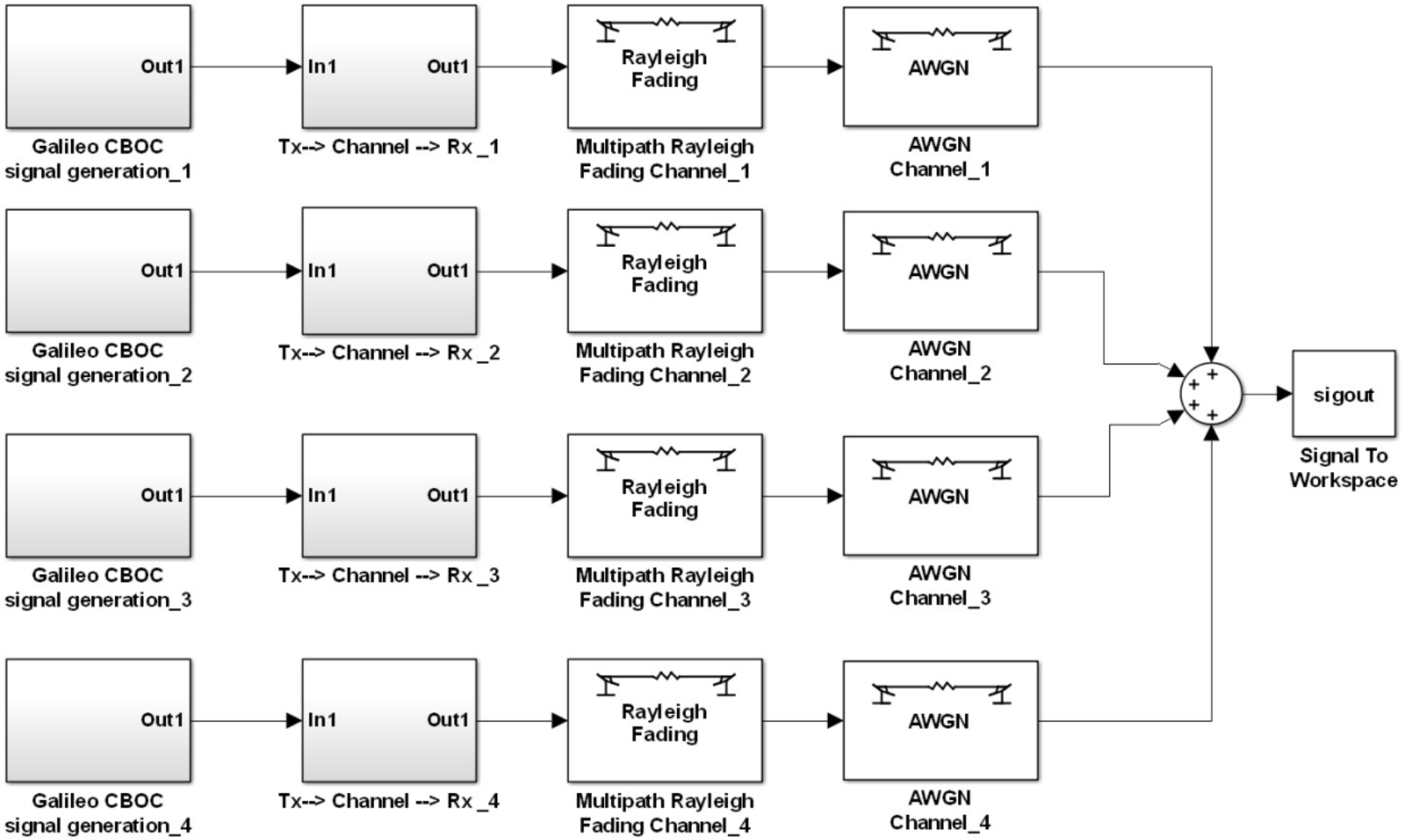


The Experimental Setup



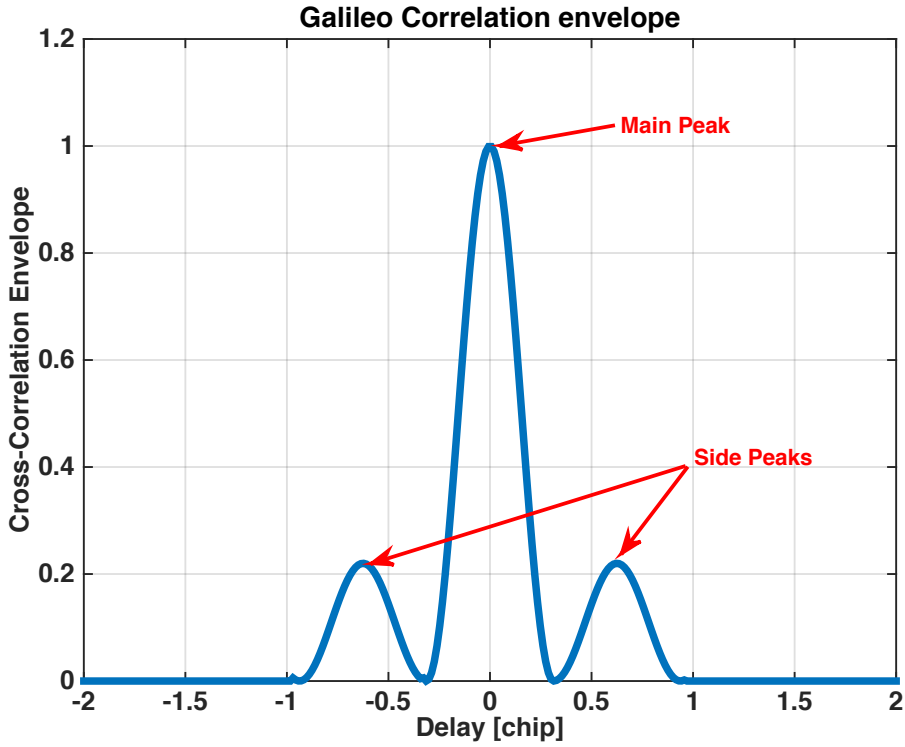
$$X_{E1} = \frac{1}{\sqrt{2}}\left[e_{E1\_B}(t)S_b - e_{E1\_C}(t)S_c\right]\cos\left(2\pi f_{E1}t\right)$$

The Experimental Setup

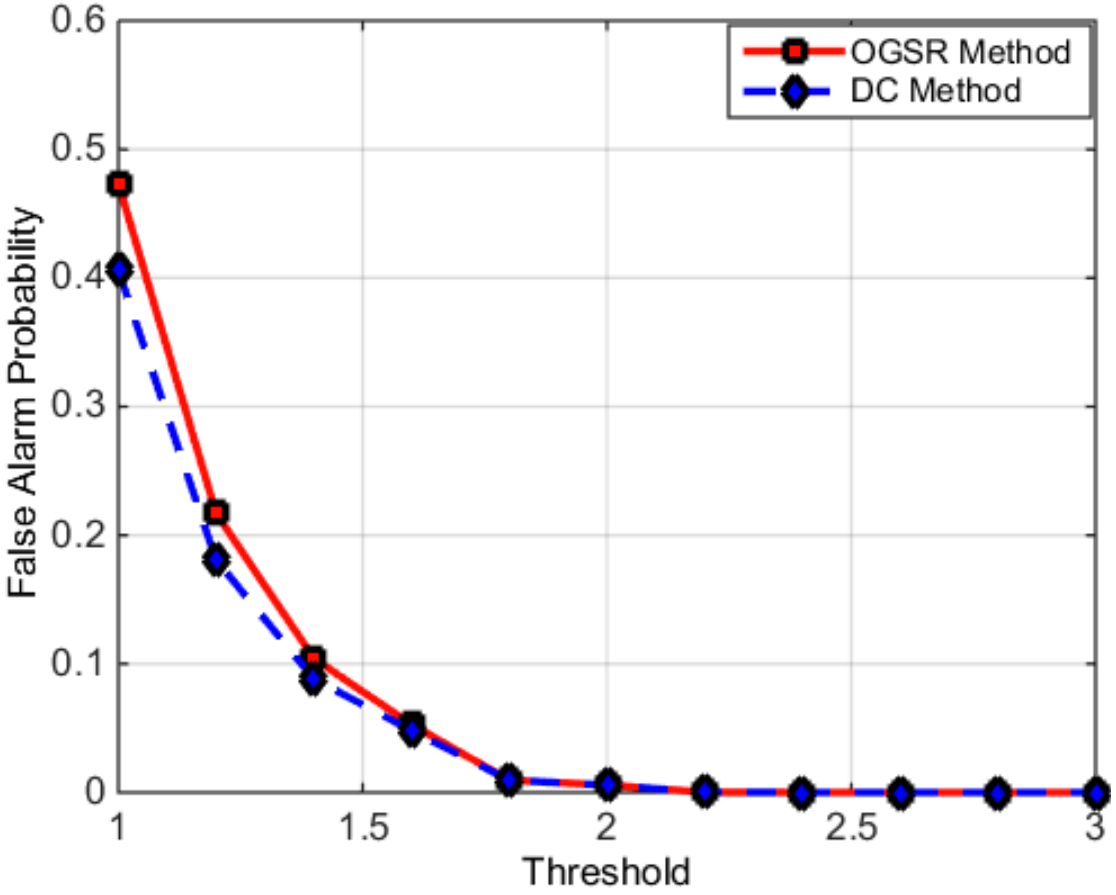


Analysis
Main peak to side peak and noise ratio

Method	OGSR Method		DC Method	
	-145 dBm	-150 dBm	-145 dBm	-150 dBm
Correlation Power	77.06	75.39	72.59	70.71
Highest Peak to the second Peak	3.3	2.4	3.4	2.2
Highest Peak to the noise level	5.1	3.5	7.05	5.59



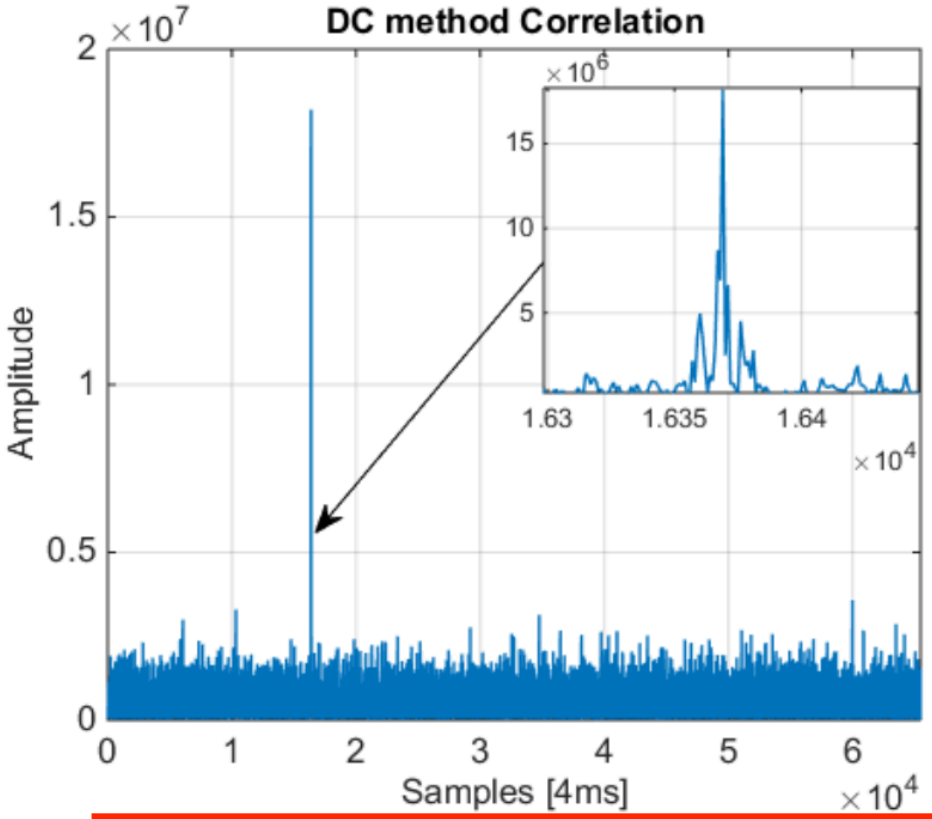
Analysis
False Alarm Probability vs. Threshold

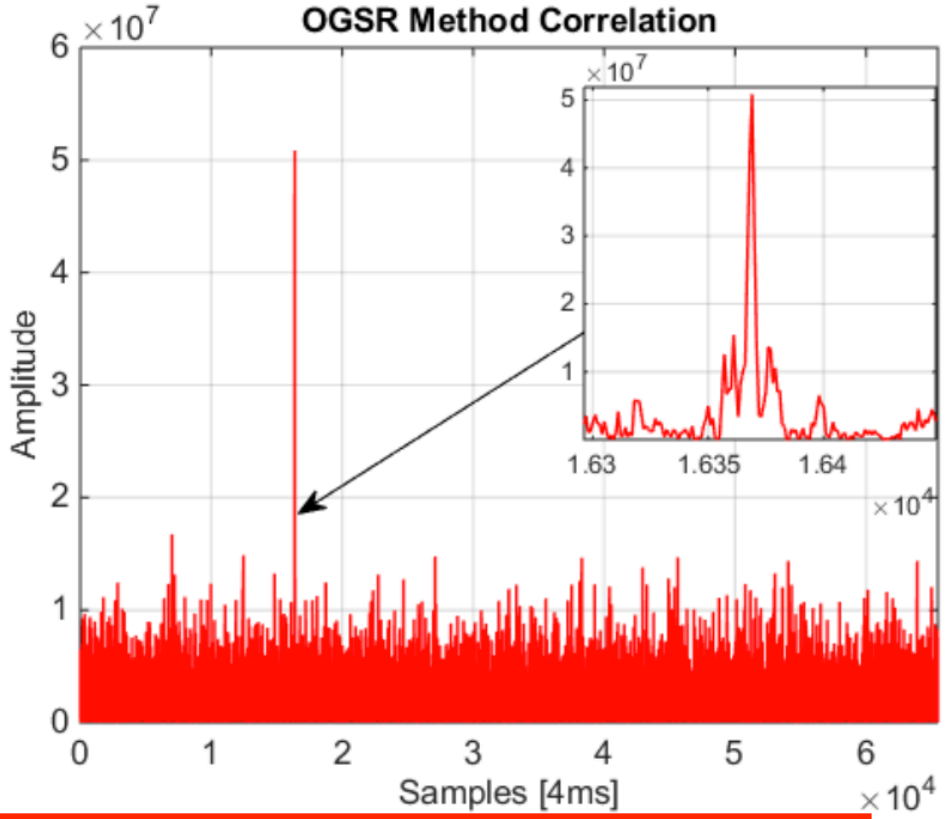


- **When the Threshold = 1.8**
  - The **False alarm probability** is **increased** for both methods
- **When the Threshold = 2.5**
  - This lead to **reducing** both of the **probability of detection** and the **false alarm probability**
- **While, when the Threshold = 2**
  - This will allow acquiring **present Galileo** signal and also at this value the **False alarm** is equal to zero

Analysis
Highest correlation peak outputs

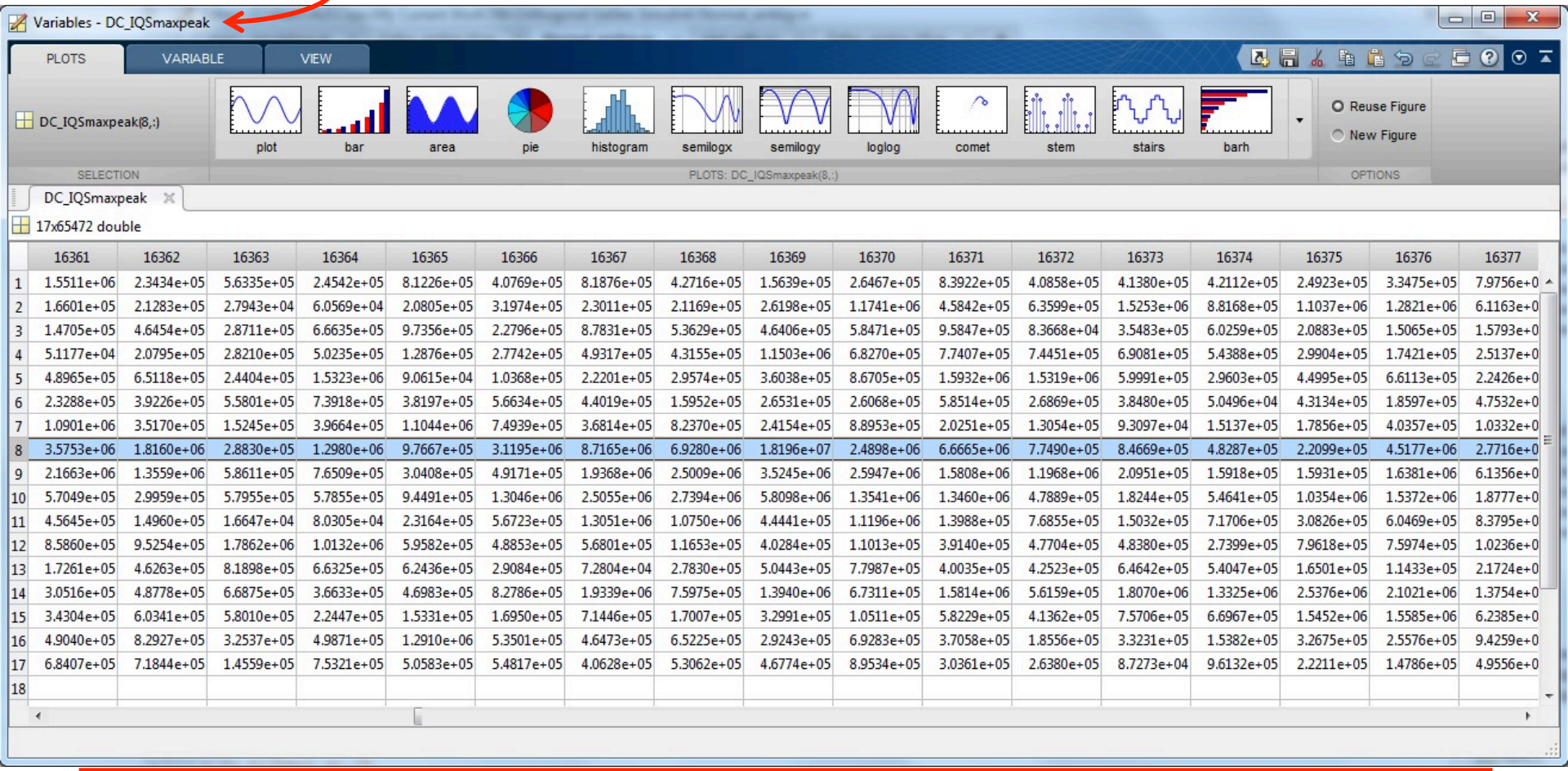
- OGSR correlation is around 2.7 > the DC correlation
  - But
- The noise level in our OGSR is 28% higher than in the DC method





Analysis
Doppler frequency bin steps correlation

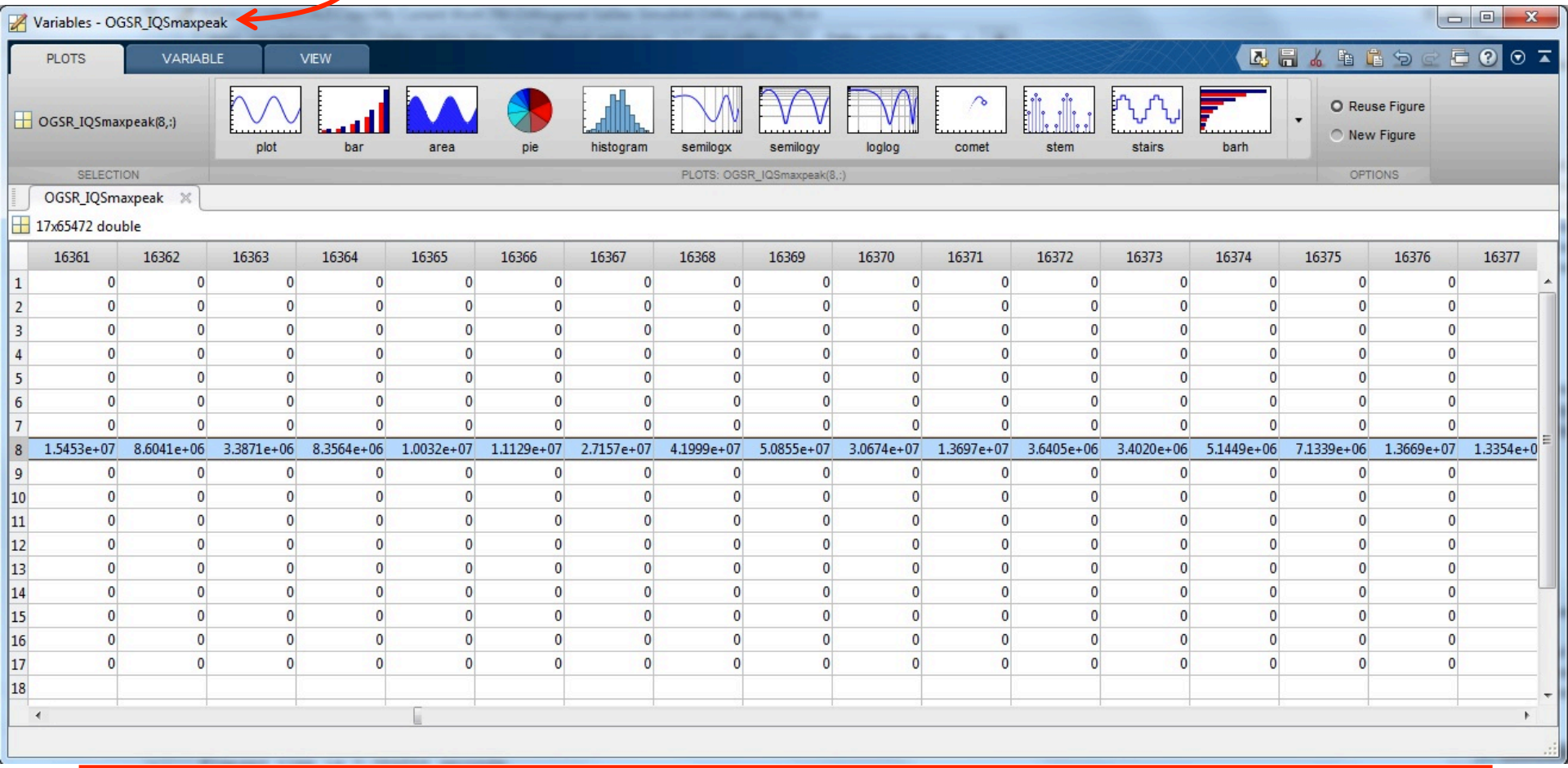
DC Method



	16361	16362	16363	16364	16365	16366	16367	16368	16369	16370	16371	16372	16373	16374	16375	16376	16377
1	1.5511e+06	2.3434e+05	5.6335e+05	2.4542e+05	8.1226e+05	4.0769e+05	8.1876e+05	4.2716e+05	1.5639e+05	2.6467e+05	8.3922e+05	4.0858e+05	4.1380e+05	4.2112e+05	2.4923e+05	3.3475e+05	7.9756e+0
2	1.6601e+05	2.1283e+05	2.7943e+04	6.0569e+04	2.0805e+05	3.1974e+05	2.3011e+05	2.1169e+05	2.6198e+05	1.1741e+06	4.5842e+05	6.3599e+05	1.5253e+06	8.8168e+05	1.1037e+06	1.2821e+06	6.1163e+0
3	1.4705e+05	4.6454e+05	2.8711e+05	6.6635e+05	9.7356e+05	2.2796e+05	8.7831e+05	5.3629e+05	4.6406e+05	5.8471e+05	9.5847e+05	8.3668e+04	3.5483e+05	6.0259e+05	2.0883e+05	1.5065e+05	1.5793e+0
4	5.1177e+04	2.0795e+05	2.8210e+05	5.0235e+05	1.2876e+05	2.7742e+05	4.9317e+05	4.3155e+05	1.1503e+06	6.8270e+05	7.7407e+05	7.4451e+05	6.9081e+05	5.4388e+05	2.9904e+05	1.7421e+05	2.5137e+0
5	4.8965e+05	6.5118e+05	2.4404e+05	1.5323e+06	9.0615e+04	1.0368e+05	2.2201e+05	2.9574e+05	3.6038e+05	8.6705e+05	1.5932e+06	1.5319e+06	5.9991e+05	2.9603e+05	4.4995e+05	6.6113e+05	2.2426e+0
6	2.3288e+05	3.9226e+05	5.5801e+05	7.3918e+05	3.8197e+05	5.6634e+05	4.4019e+05	1.5952e+05	2.6531e+05	2.6068e+05	5.8514e+05	2.6869e+05	3.8480e+05	5.0496e+04	4.3134e+05	1.8597e+05	4.7532e+0
7	1.0901e+06	3.5170e+05	1.5245e+05	3.9664e+05	1.1044e+06	7.4939e+05	3.6814e+05	8.2370e+05	2.4154e+05	8.8953e+05	2.0251e+05	1.3054e+05	9.3097e+04	1.5137e+05	1.7856e+05	4.0357e+05	1.0332e+0
8	3.5753e+06	1.8160e+06	2.8830e+05	1.2980e+06	9.7667e+05	3.1195e+06	8.7165e+06	6.9280e+06	1.8196e+07	2.4898e+06	6.6665e+06	7.7490e+05	8.4669e+05	4.8287e+05	2.2099e+05	4.5177e+06	2.7716e+0
9	2.1663e+06	1.3559e+06	5.8611e+05	7.6509e+05	3.0408e+05	4.9171e+05	1.9368e+06	2.5009e+06	3.5245e+06	2.5947e+06	1.5808e+06	1.1968e+06	2.0951e+05	1.5918e+05	1.5931e+05	1.6381e+06	6.1356e+0
10	5.7049e+05	2.9959e+05	5.7955e+05	5.7855e+05	9.4491e+05	1.3046e+06	2.5055e+06	2.7394e+06	5.8098e+06	1.3541e+06	1.3460e+06	4.7889e+05	1.8244e+05	5.4641e+05	1.0354e+06	1.5372e+06	1.8777e+0
11	4.5645e+05	1.4960e+05	1.6647e+04	8.0305e+04	2.3164e+05	5.6723e+05	1.3051e+06	1.0750e+06	4.4441e+05	1.1196e+06	1.3988e+05	7.6855e+05	1.5032e+05	7.1706e+05	3.0826e+05	6.0469e+05	8.3795e+0
12	8.5860e+05	9.5254e+05	1.7862e+06	1.0132e+06	5.9582e+05	4.8853e+05	5.6801e+05	1.1653e+05	4.0284e+05	1.1013e+05	3.9140e+05	4.7704e+05	4.8380e+05	2.7399e+05	7.9618e+05	7.5974e+05	1.0236e+0
13	1.7261e+05	4.6263e+05	8.1898e+05	6.6325e+05	6.2436e+05	2.9084e+05	7.2804e+04	2.7830e+05	5.0443e+05	7.7987e+05	4.0035e+05	4.2523e+05	6.4642e+05	5.4047e+05	1.6501e+05	1.1433e+05	2.1724e+0
14	3.0516e+05	4.8778e+05	6.6875e+05	3.6633e+05	4.6983e+05	8.2786e+05	1.9339e+06	7.5975e+05	1.3940e+06	6.7311e+05	1.5814e+06	5.6159e+05	1.8070e+06	1.3325e+06	2.5376e+06	2.1021e+06	1.3754e+0
15	3.4304e+05	6.0341e+05	5.8010e+05	2.2447e+05	1.5331e+05	1.6950e+05	7.1446e+05	1.7007e+05	3.2991e+05	1.0511e+05	5.8229e+05	4.1362e+05	7.5706e+05	6.6967e+05	1.5452e+06	1.5585e+06	6.2385e+0
16	4.9040e+05	8.2927e+05	3.2537e+05	4.9871e+05	1.2910e+06	5.3501e+05	4.6473e+05	6.5225e+05	2.9243e+05	6.9283e+05	3.7058e+05	1.8556e+05	3.3231e+05	1.5382e+05	3.2675e+05	2.5576e+05	9.4259e+0
17	6.8407e+05	7.1844e+05	1.4559e+05	7.5321e+05	5.0583e+05	5.4817e+05	4.0628e+05	5.3062e+05	4.6774e+05	8.9534e+05	3.0361e+05	2.6380e+05	8.7273e+04	9.6132e+05	2.2211e+05	1.4786e+05	4.9556e+0
18																	

Analysis
Doppler frequency bin steps correlation

OGSR Method



	16361	16362	16363	16364	16365	16366	16367	16368	16369	16370	16371	16372	16373	16374	16375	16376	16377
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
8	1.5453e+07	8.6041e+06	3.3871e+06	8.3564e+06	1.0032e+07	1.1129e+07	2.7157e+07	4.1999e+07	5.0855e+07	3.0674e+07	1.3697e+07	3.6405e+06	3.4020e+06	5.1449e+06	7.1339e+06	1.3669e+07	1.3354e+0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18																	

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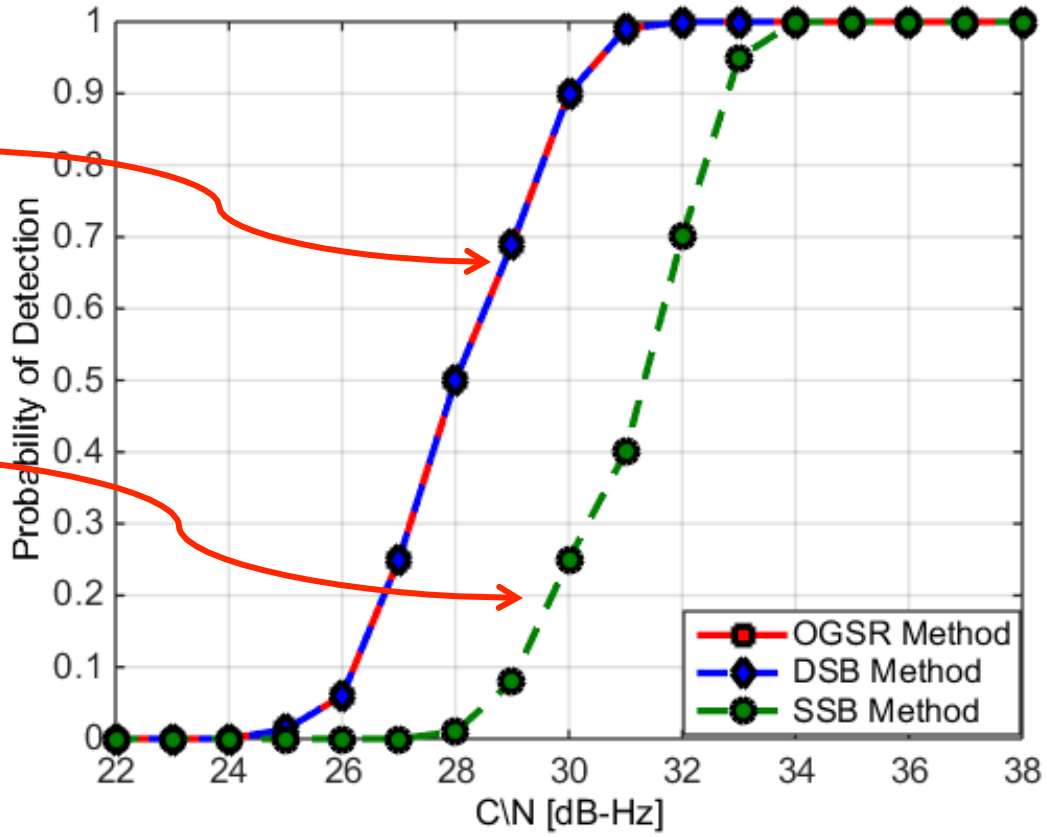
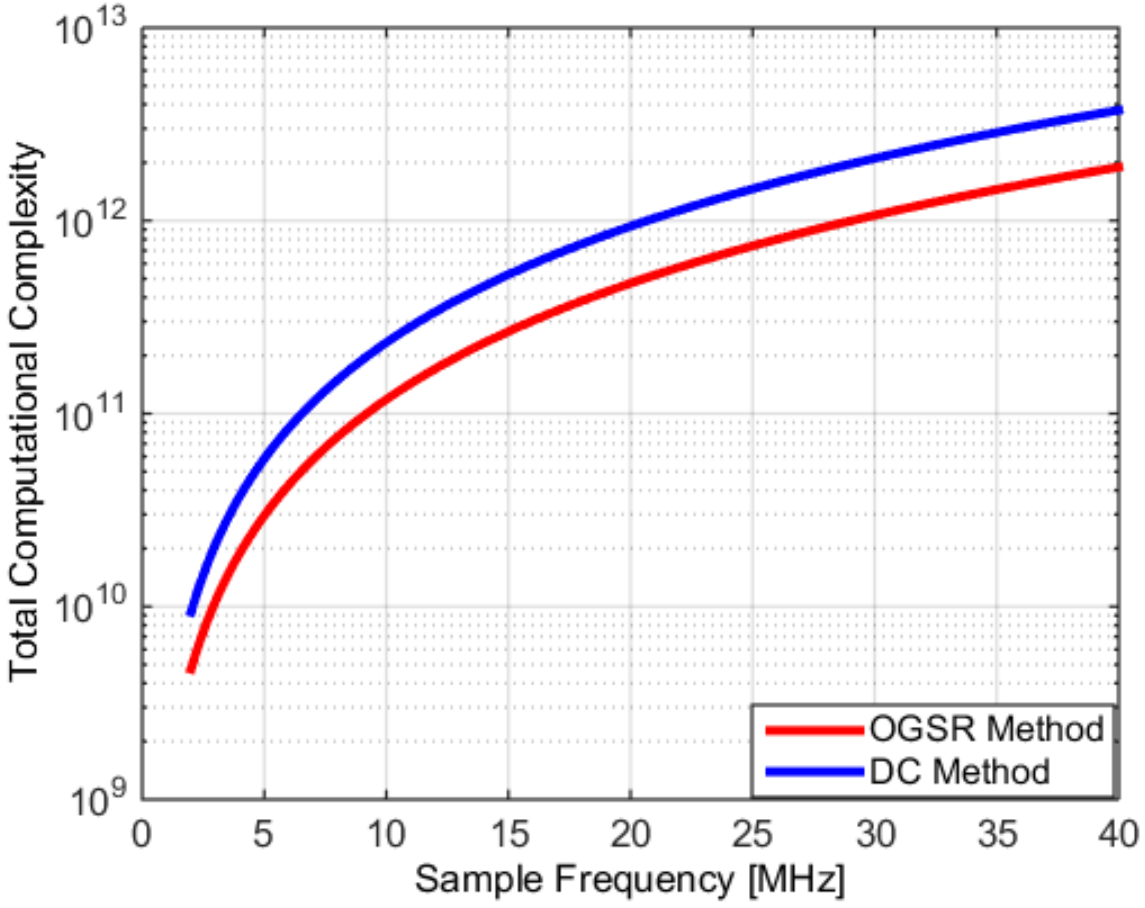
Result
Performance

- OGSR performs as good as DC method
- OGSR maintains the 3dB joining acquisition gain
  - 2.8dB better than SC method



Result Complexity



- **OGSR constructs the locally generated signal in Orthogonal format, therefore the computational complexity is**
  - **about 49% < DC method**

Result
Processing Time

- Monte Carlo simulations with 100 runs to calculate the average processing time

Method	Average Processing Time
SC Method	6.6274 sec.
OGSR Method	6.6306 sec.
DC Method	10.1636 sec.

OGSR_Time ≈ SC_Time

OGSR_Time 35% < DC_Time

Conclusions

- Our OGSR forms the Data and the Pilot signals in an Orthogonal format
- OGSR method performs as good as DC method
  - i.e. is maintained the **3dB joining gain** that achieved by exploiting the power in both data and pilot signals
- OGSR method saves whole correlation chain in comparison with:
  - Time-Domain implementation **4-Correlation Channels**
  - Frequency-Domain implementation **2-Correlation Channels**
- The outcomes are:
  - Less complex implementation **(49%)** less computationally expensive than the **DC** method
  - Faster acquisition process **(35%)** less time required than the DC method
- OGSR a good candidate for Smartphone's software receiver

Questions?