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Compressive sampling technique for limited link budget communication channel implementation

G.Gaigals, M.Greitāns, A.Andziulis

Gatis Gaigals
researcher
ERI “VIRAC” of VUC

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Content

- CS technique
- Aim and methodology
- CS on CubeSAT transmitter side
- CS on CubeSAT receiver side
- CS for communication channel physical implementation
- Description of communication channel simulator
- Results
- An analysis of the results of experiments

Compressive sampling

- A method to acquire, store or transfer less data than usual ways

- For given data **x** calculate measurement **y** = **Ax,** where **A** – so called measurement matrix

- Compression: **x**[n], **y**[m], m<<n
- **x** has to have sparse representation (FT, DCT, HT, WT, sparse components s<4m, compressible data!!!)
- Easy algorithm for **y**, can achieve high speed
- Greedy algorithm for **x**, embedded implementation is very challenging
- Resistant to noise
- There are papers about channel estimation in OFDM

Aim of the work

Keeping in mind satellite communication systems:

- analysis of CS technique application
- simulation the application of CS to estimate parameters of such application

Focusing on very limited link budget communication channels!

Methodology

- Theorethical analysis of CS application:
  - on CubeSAT transmitter side
  - on CubeSAT receiver side
- Idea of sparse orthogonal subchannel division multiplexing (implementation of physical layer)
- Development of communication channel simulator in LabVIEW to measure Bit Error Rate (BER) of experiments (OFDM, SOSDM)
- An analysis of the results of experiments

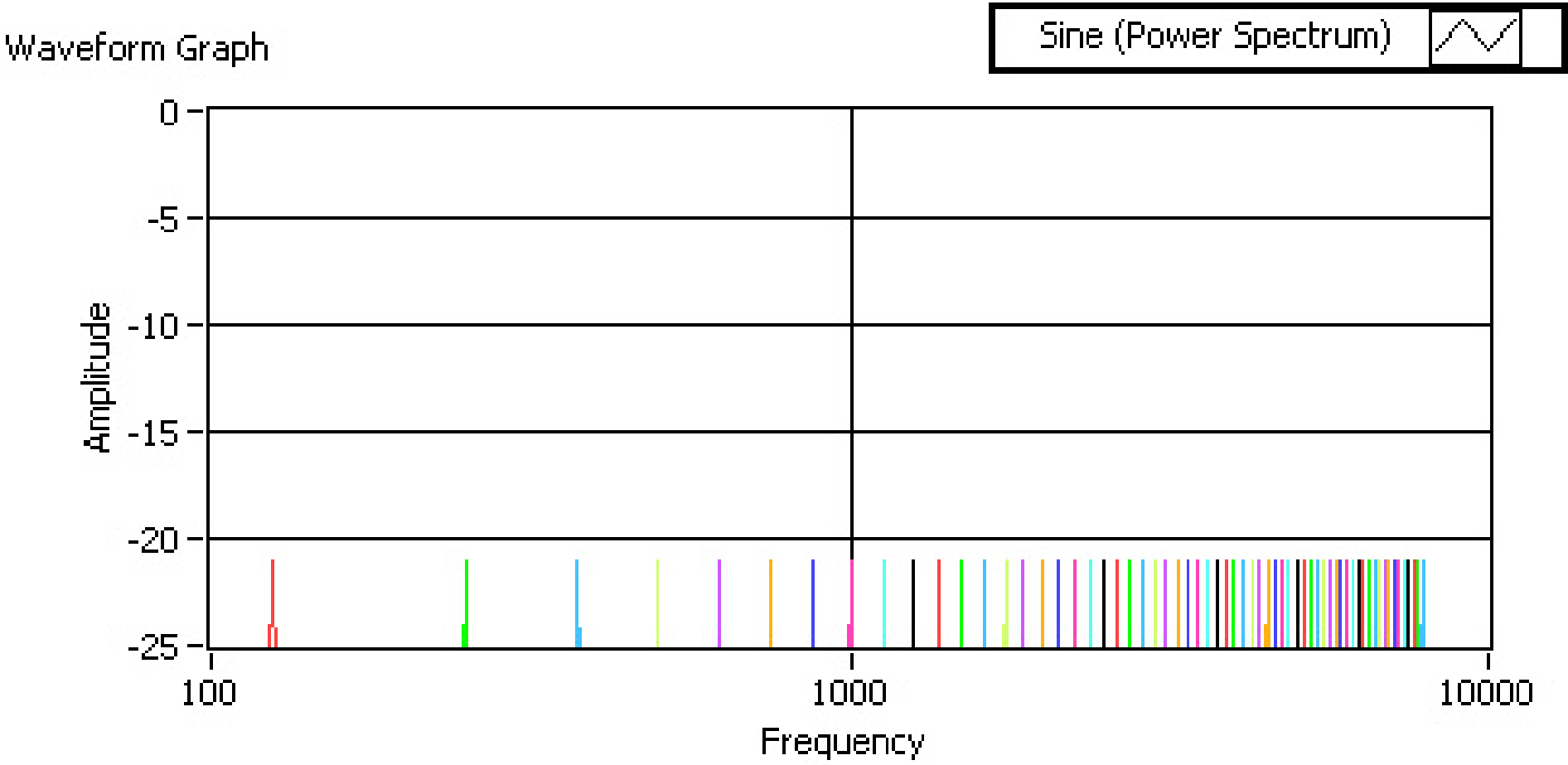
CS on CubeSAT transmitter side

- As CS works only on compressible data – compressible mission data **x** compression:
  - matrix and vector multiplication
  - can be very fast (hardware acceleration)
  - may take memory for large **A** (can be stored in MRAM/FRAM, may be generated on-fly)
  - can be combined with other compression tehniques
- Examples of source data
  - temperature, battery, magnetometer
  - mission pictures, multimedia

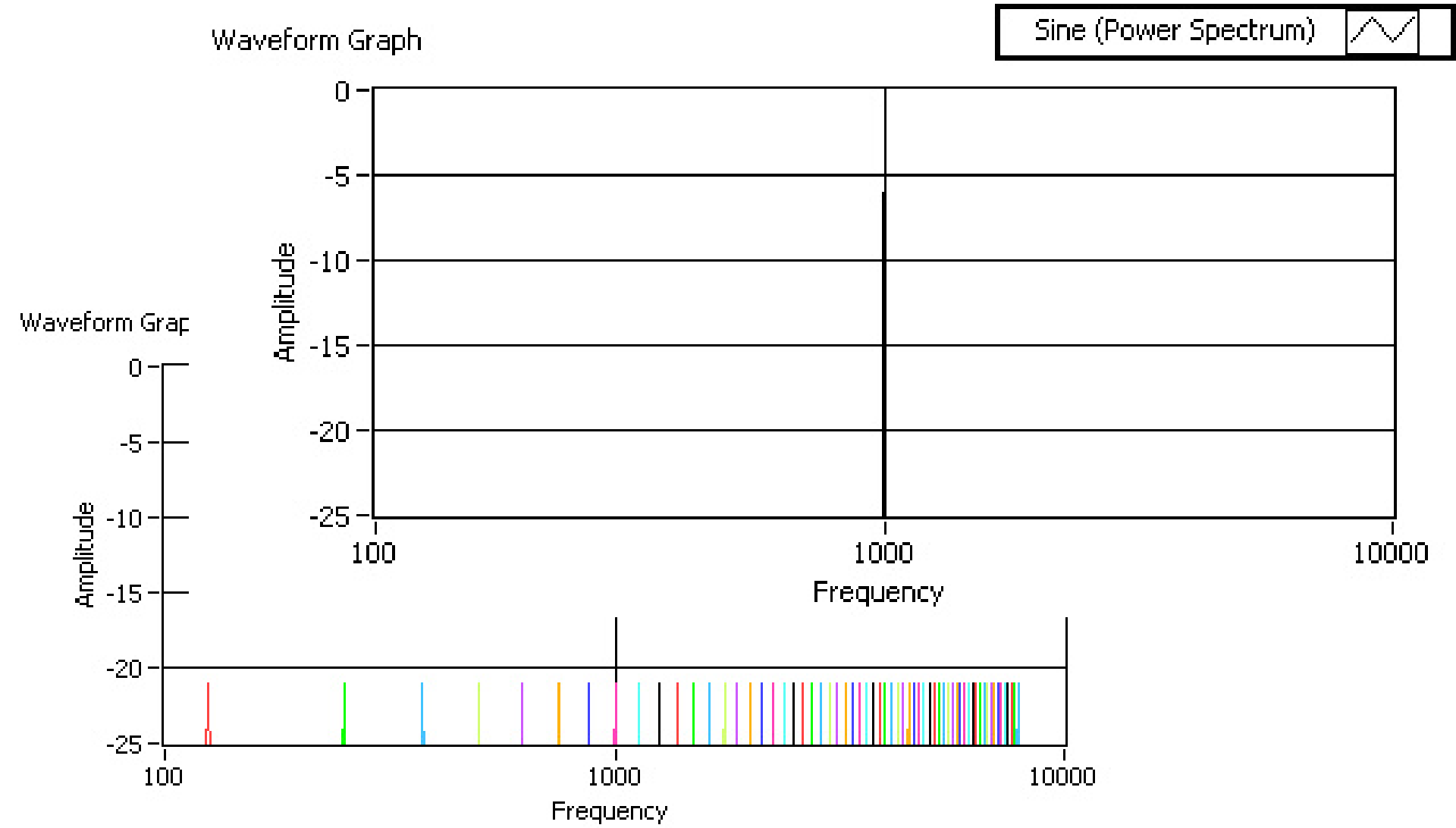
CS on CubeSAT receiver side

- Recovery of original signal **x** from transmitted from Earth measurements **y**:
  - very complicate algorithms
  - large amount of data **x**
- Usage on receiver side:
  - unreal, but possible:
    - hardware acceleration of calculations
    - implementation of communication channel
- Work on the hardware accellerator

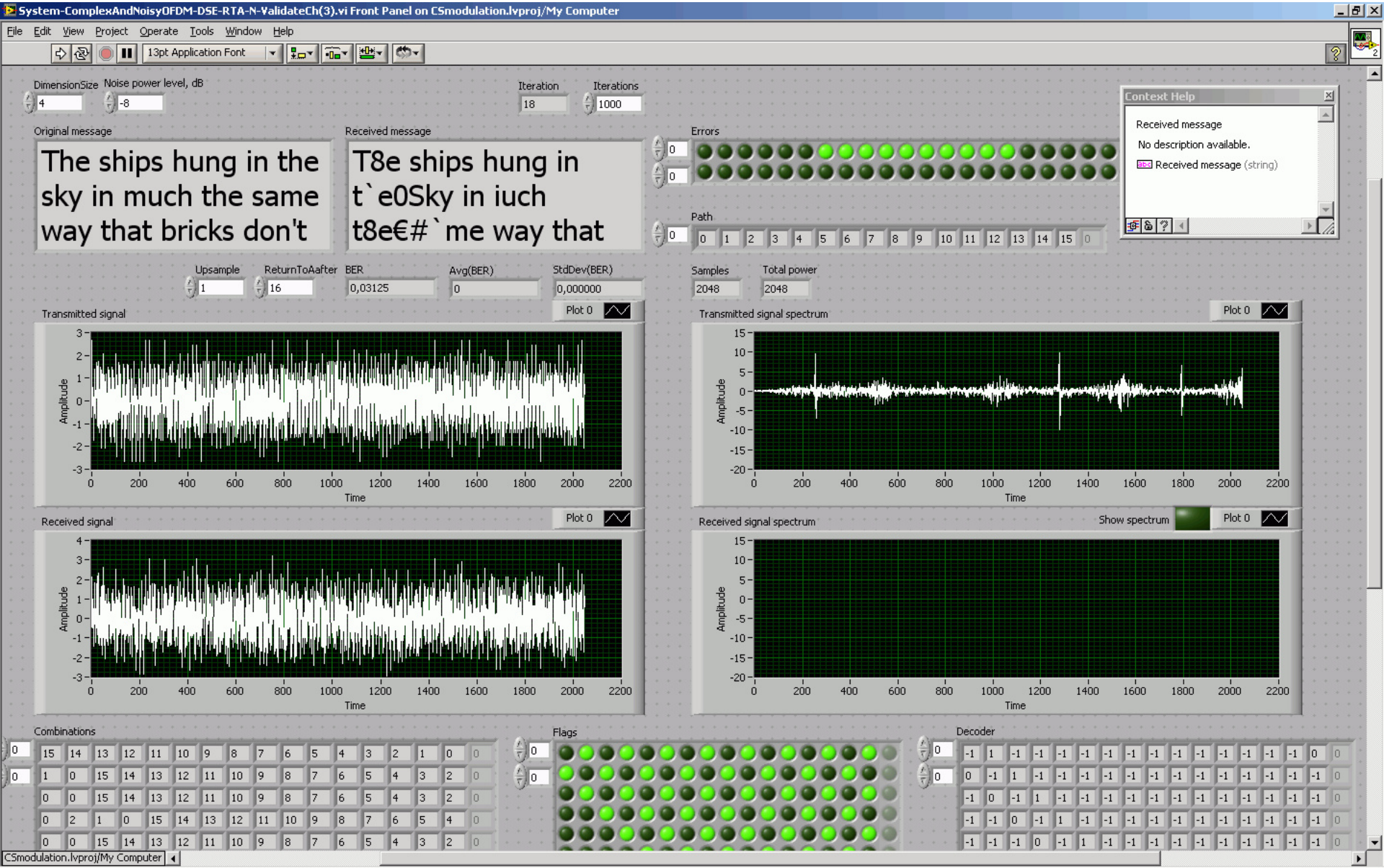
Idea of SOSDM



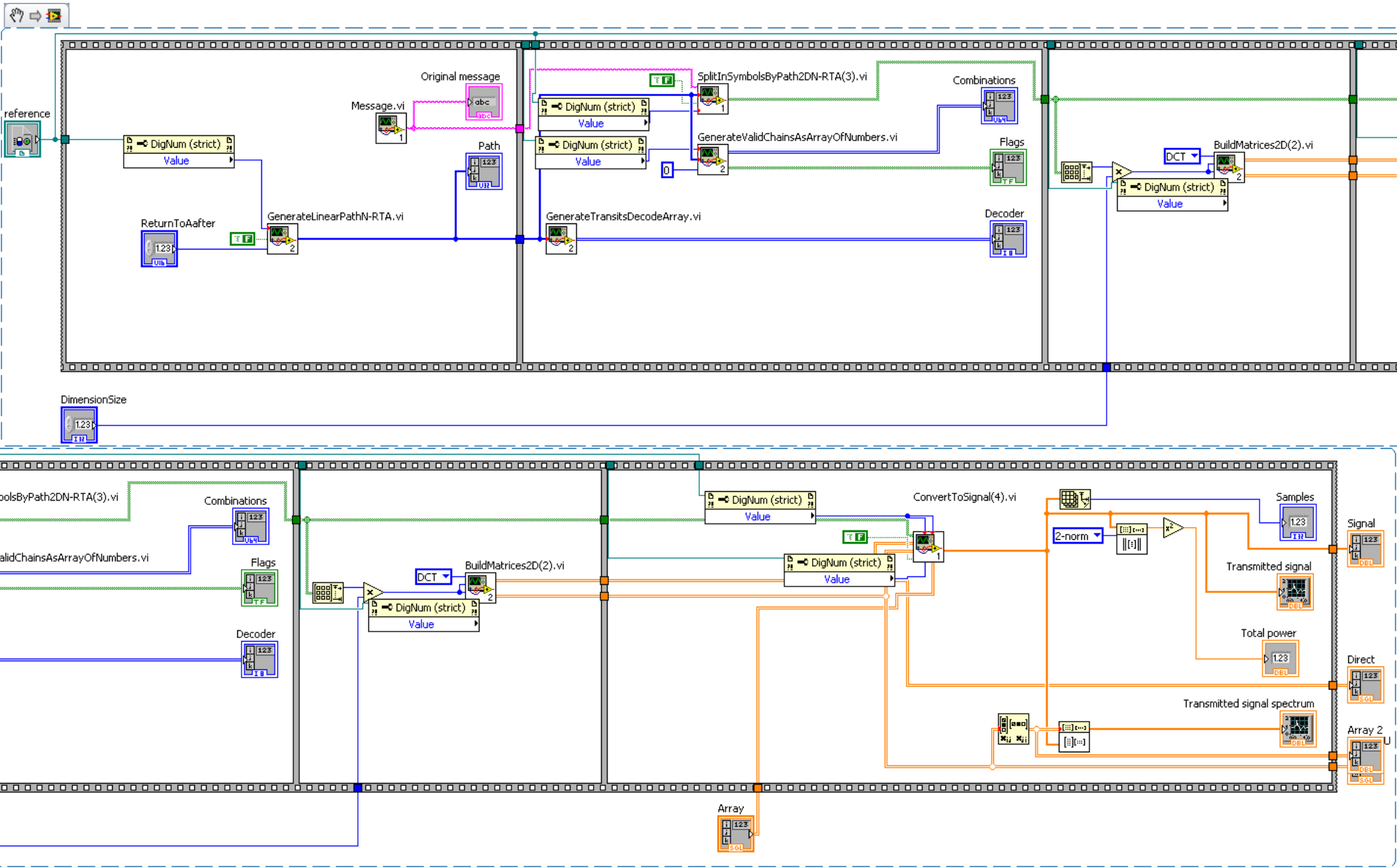
Idea of SOSDM



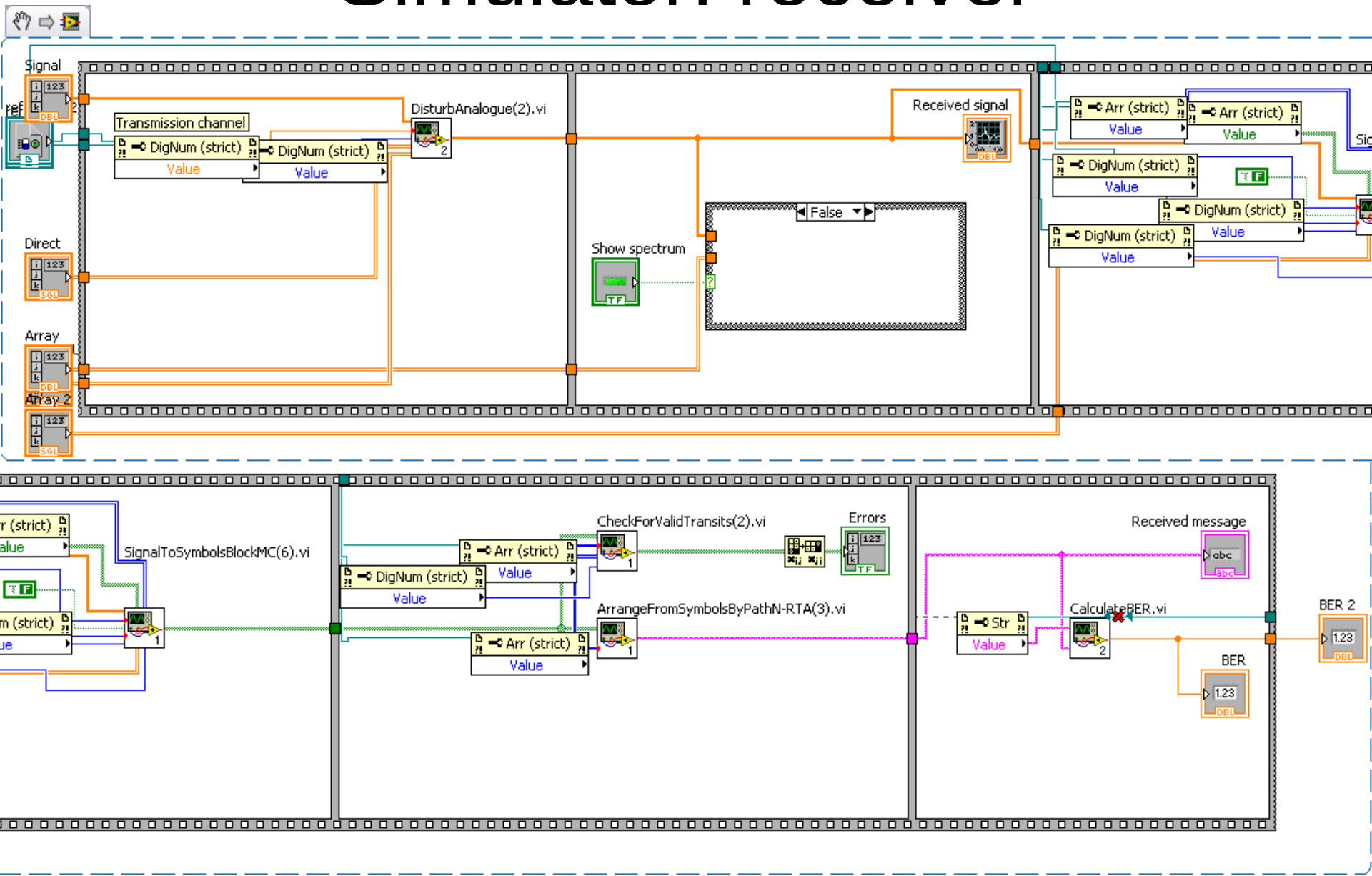
Communication channel simulator



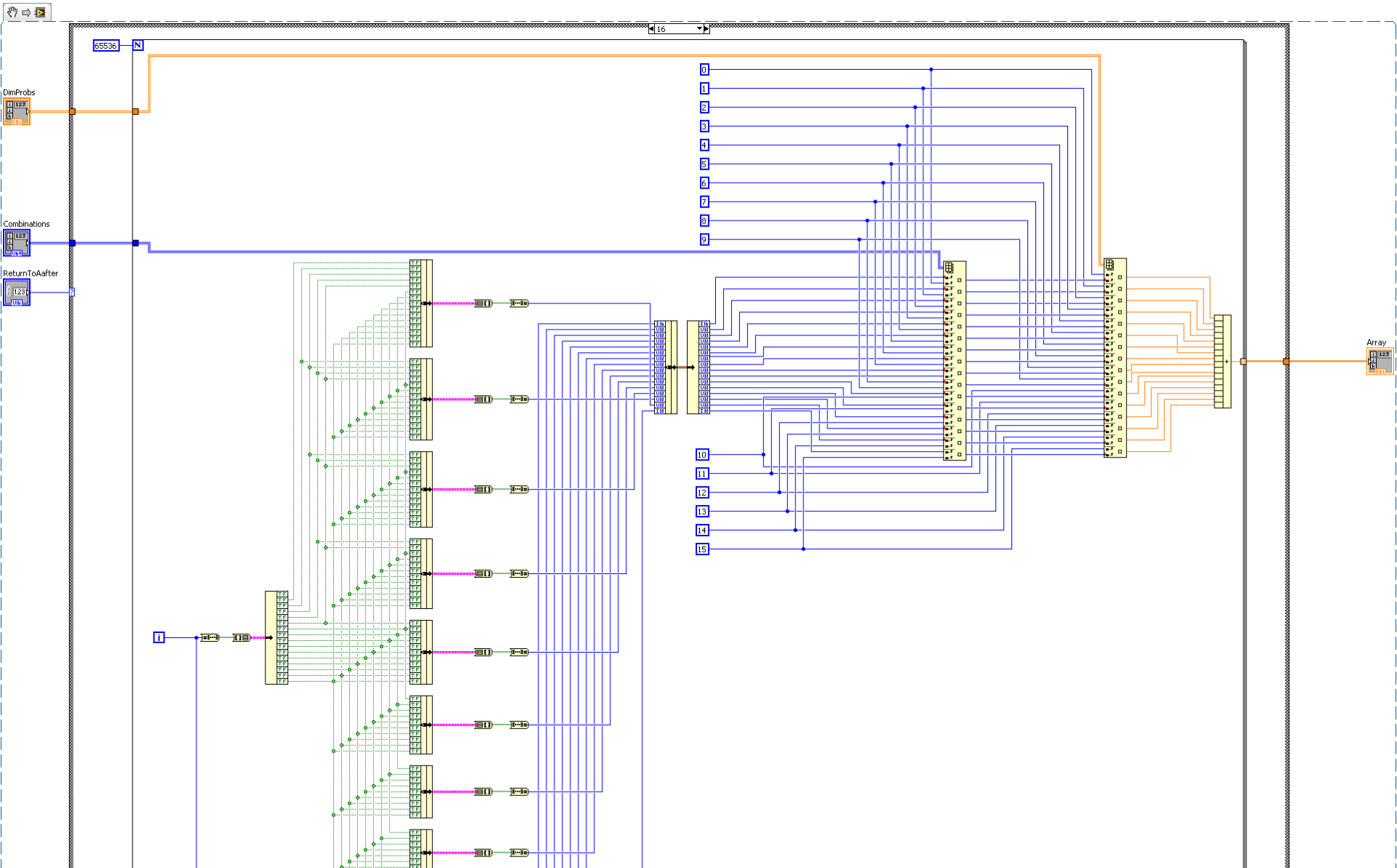
Simulator: transmitter



Simulator: receiver



Implementation specifics

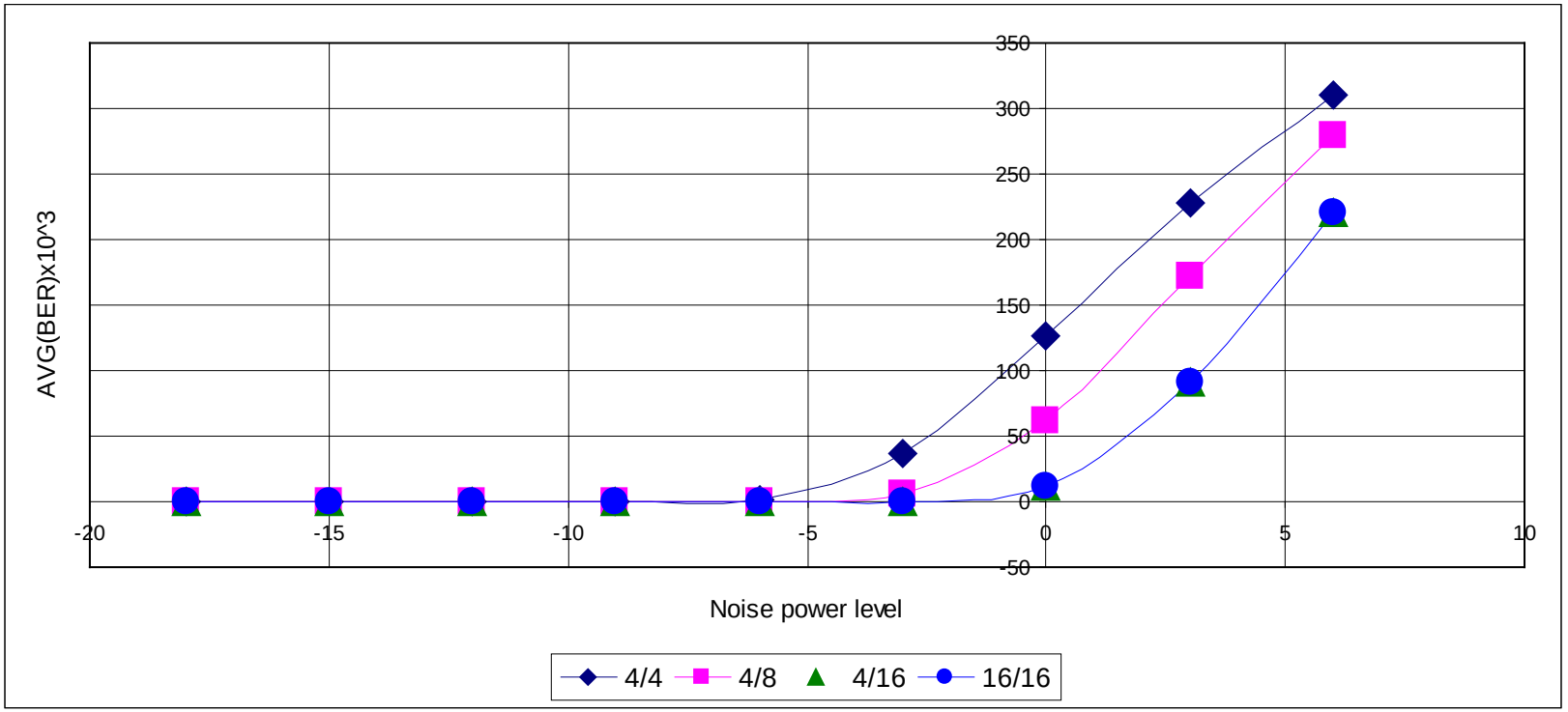


Cases analysed

- OFMD 4, 8, 16, 32 – BFSK (DCT)
- SOSDM 4, 8 (not a good case), 16:
  - DCT
  - HT
  - WT
- Additionally sparsified SOSDM4, DCT:
  - 4/8
  - 4/16
  - 16/32 failed because of LV OOM error
- Noise power levels: -18..6 dB
- Differential encoding and Markov chains for signal recovery were approved

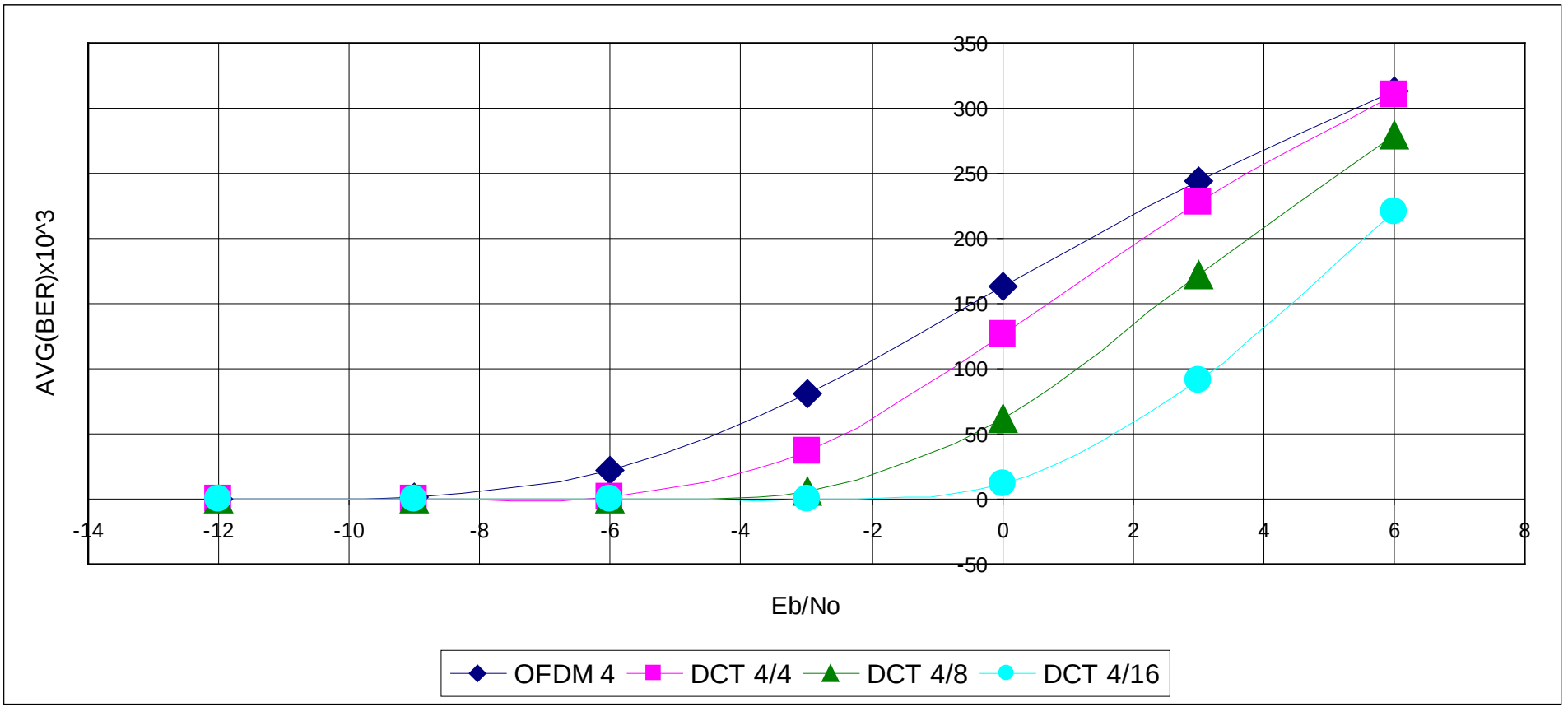
Sample of results

AVG(BER)x10^3	NPL, dB									Len(msg),	Total power
DSize	6	3	0	-3	-6	-9	-12	-15	-18	samples	
4/4	310	228	126	36,8	1,47	0	0	0	0	1024	256
4/8	279	172	61,3	5,66	0,0127	0	0	0	0	2048	256
4/16	221	91,6	12	0,103	0	0	0	0	0	4096	256
16/16	220	91	12	0,104	0	0	0	0	0	2048	128
StdDev(AVG(BER	NPL, dB										
DSize	6	3	0	-3	-6	-9	-12	-15	-18		
4/4	22,1	20,6	16,5	9,57	2	0	0	0	0		
4/8	22,3	19	12,6	4,01	0,192	0	0	0	0		
4/16	21,1	15,2	5,81	0,76	0	0	0	0	0		
16/16	26,1	19	7,46	0,715	0	0	0	0	0		



Analysis of results

E_b/N_0, dB	-9	-6	-3	0	3	6	8
OFDM 4	313	244	163	80,9	21,9	1,4	0,000195
DCT 4/4		310	228	126	36,8	1,47	0
DCT 4/8			279	172	61,3	5,66	0,0127
DCT 4/16				221	91,6	12	0,103



Conclusion

- CS on transmitter side - ☺
  - compressible signals
  - non compressible signals
- CS on receiver side - :/
- CS in receiver and transmitter of physical layer – stay at OFDM better!
- For good quality channels SOSDM demands less power
- Differential encoding, predefined path symbol transfer and Markov chains are easier to implement on CS based receiver
- FPGA as CS receiver/transmitter signal-path hardware
- On-fly reprogrammable and reconfigurable communication subsystem in orbit

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Thank you!