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Compressive sampling technique for limited link budget communication channel implementation

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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 \mathbf{x} calculate measurement $\mathbf{y} = \mathbf{Ax}$, where \mathbf{A} – so called measurement matrix
- Compression: $\mathbf{x}[n]$, $\mathbf{y}[m]$, $m \ll n$
- \mathbf{x} has to have sparse representation (FT, DCT, HT, WT, sparse components $s \ll m$, compressible data!!!)
- Easy algorithm for \mathbf{y} , can achieve high speed
- Greedy algorithm for \mathbf{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

- Theoretical 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 \times compression:
 - matrix and vector multiplication
 - can be very fast (hardware acceleration)
 - may take memory for large \mathbf{A} (can be stored in MRAM/FRAM, may be generated on-fly)
 - can be combined with other compression techniques
- Examples of source data
 - temperature, battery, magnetometer
 - mission pictures, multimedia

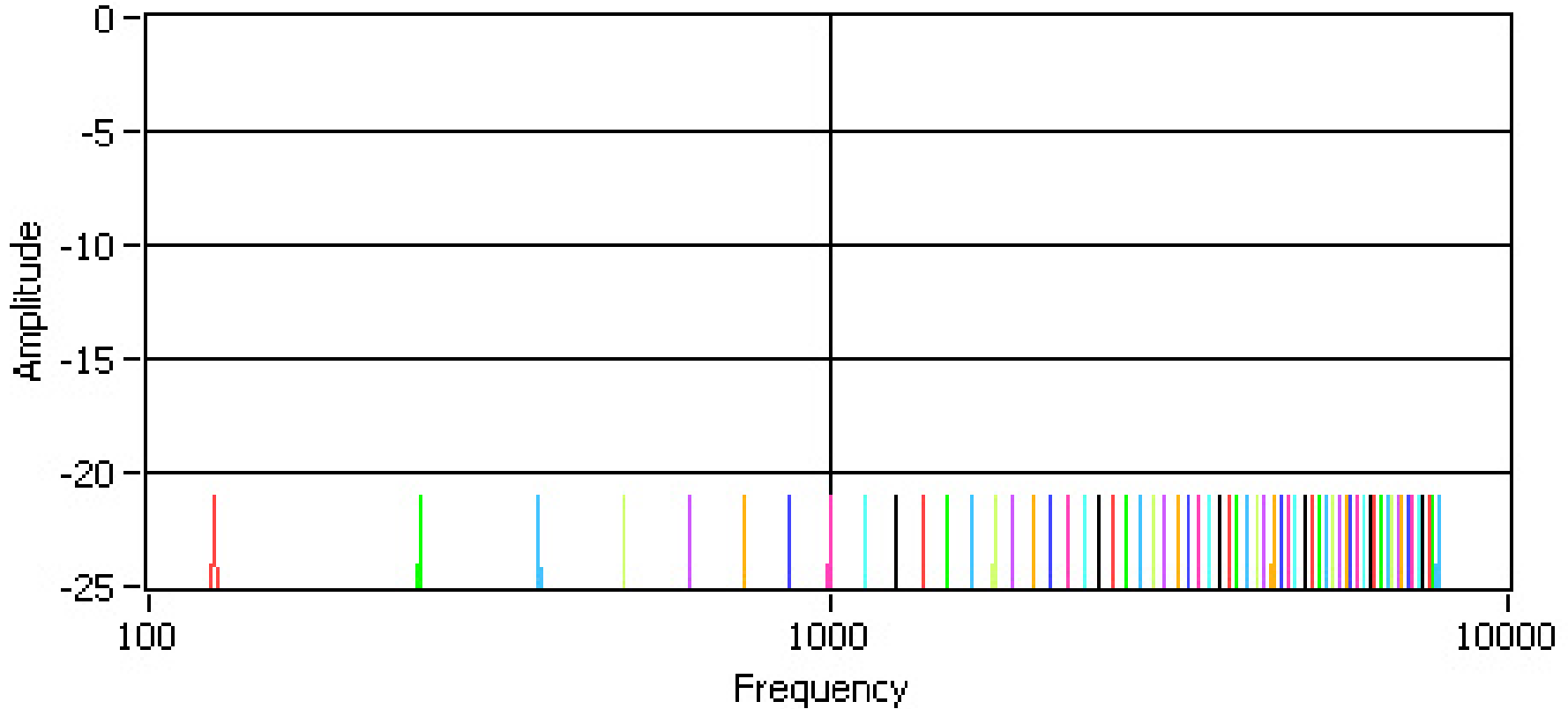
CS on CubeSAT receiver side

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

Idea of SOSDM

Waveform Graph

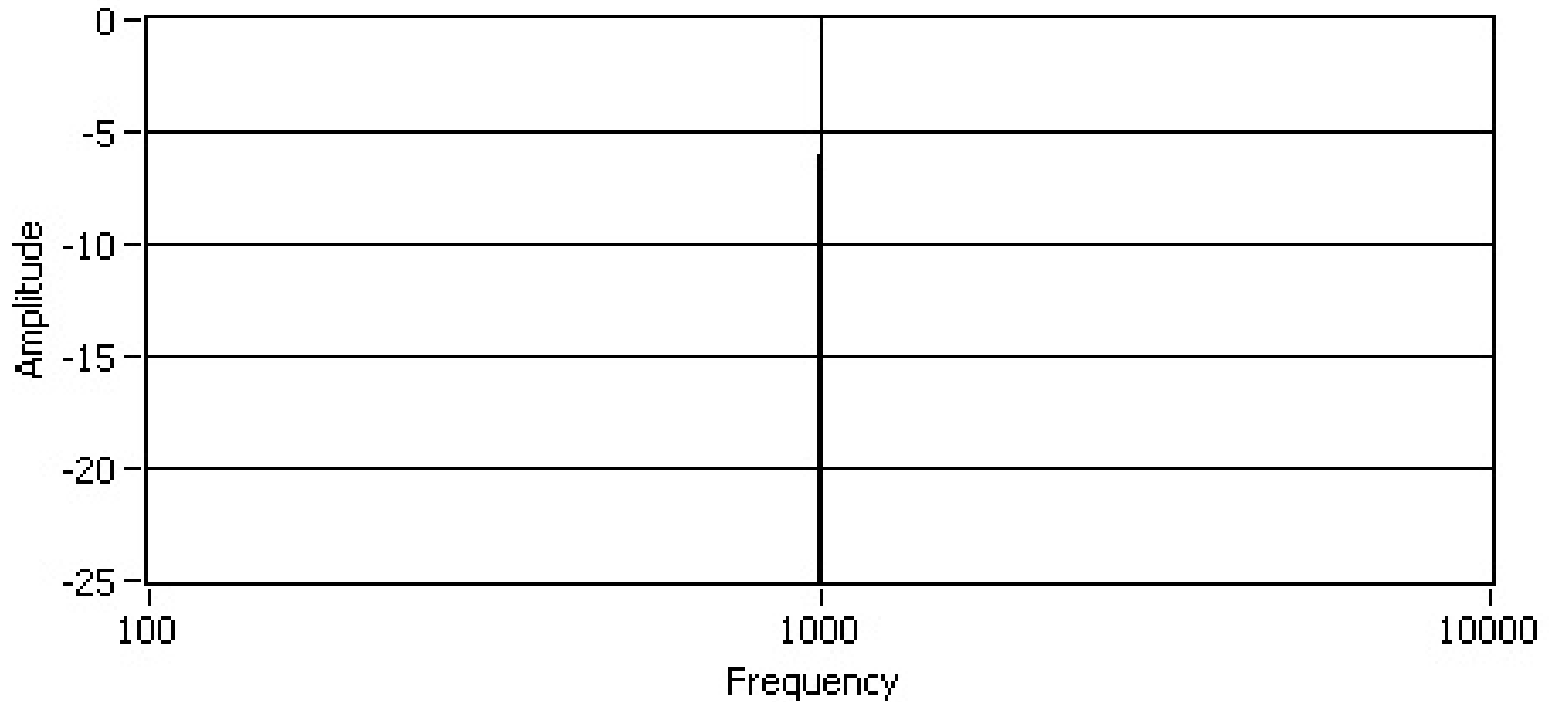
Sine (Power Spectrum)



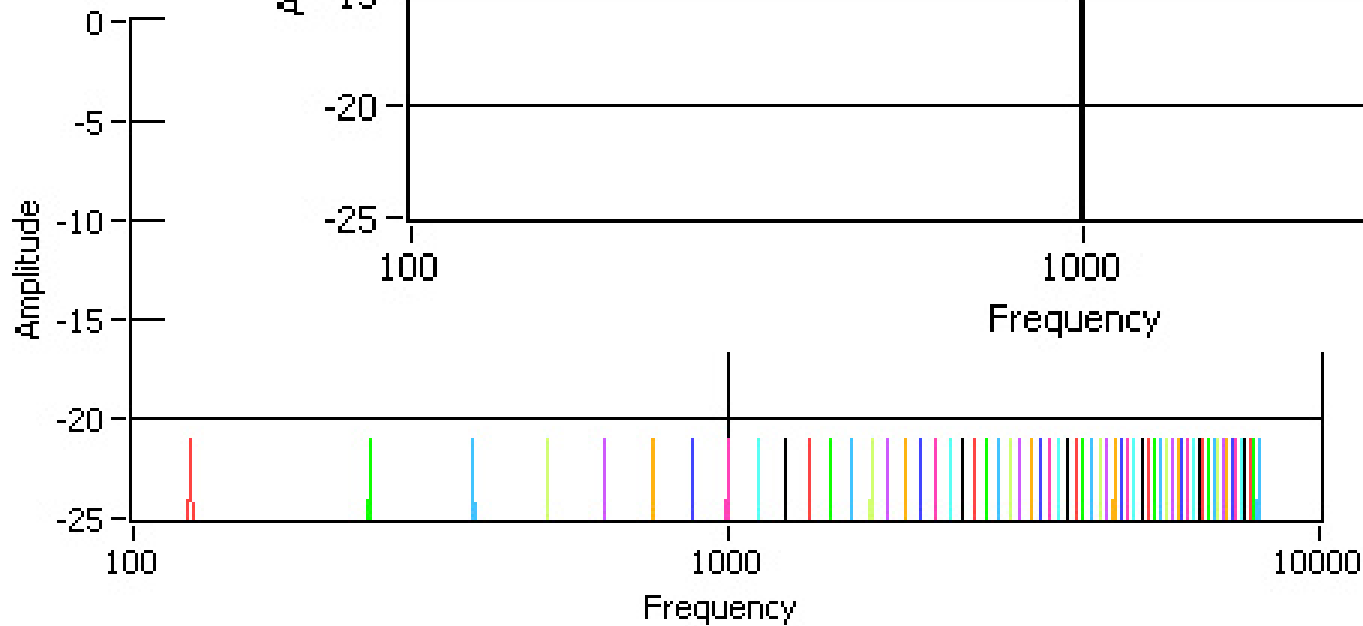
Idea of SOSDM

Waveform Graph

Sine (Power Spectrum)



Waveform Graph



Communication channel simulator

System-ComplexAndNoisyOFDM-DSE-RTA-N-ValidateCh(3).vi Front Panel on CSmodulation.lvproj/My Computer

File Edit View Project Operate Tools Window Help

13pt Application Font

DimensionSize: 4 Noise power level, dB: -8 Iteration: 18 Iterations: 1000

Original message: The ships hung in the sky in much the same way that bricks don't

Received message: T8e ships hung in t` e0Sky in iuch t8e€#` me way that

Errors: [Visual indicator showing error status]

Path: [Visual indicator showing path status]

Upsample: 1 ReturnToAafter: 16 BER: 0,03125 Avg(BER): 0 StdDev(BER): 0,000000

Samples: 2048 Total power: 2048

Transmitted signal: [Plot of transmitted signal amplitude vs time]

Transmitted signal spectrum: [Plot of transmitted signal spectrum amplitude vs time]

Received signal: [Plot of received signal amplitude vs time]

Received signal spectrum: [Plot of received signal spectrum amplitude vs time]

Combinations: [Grid of bit combinations]

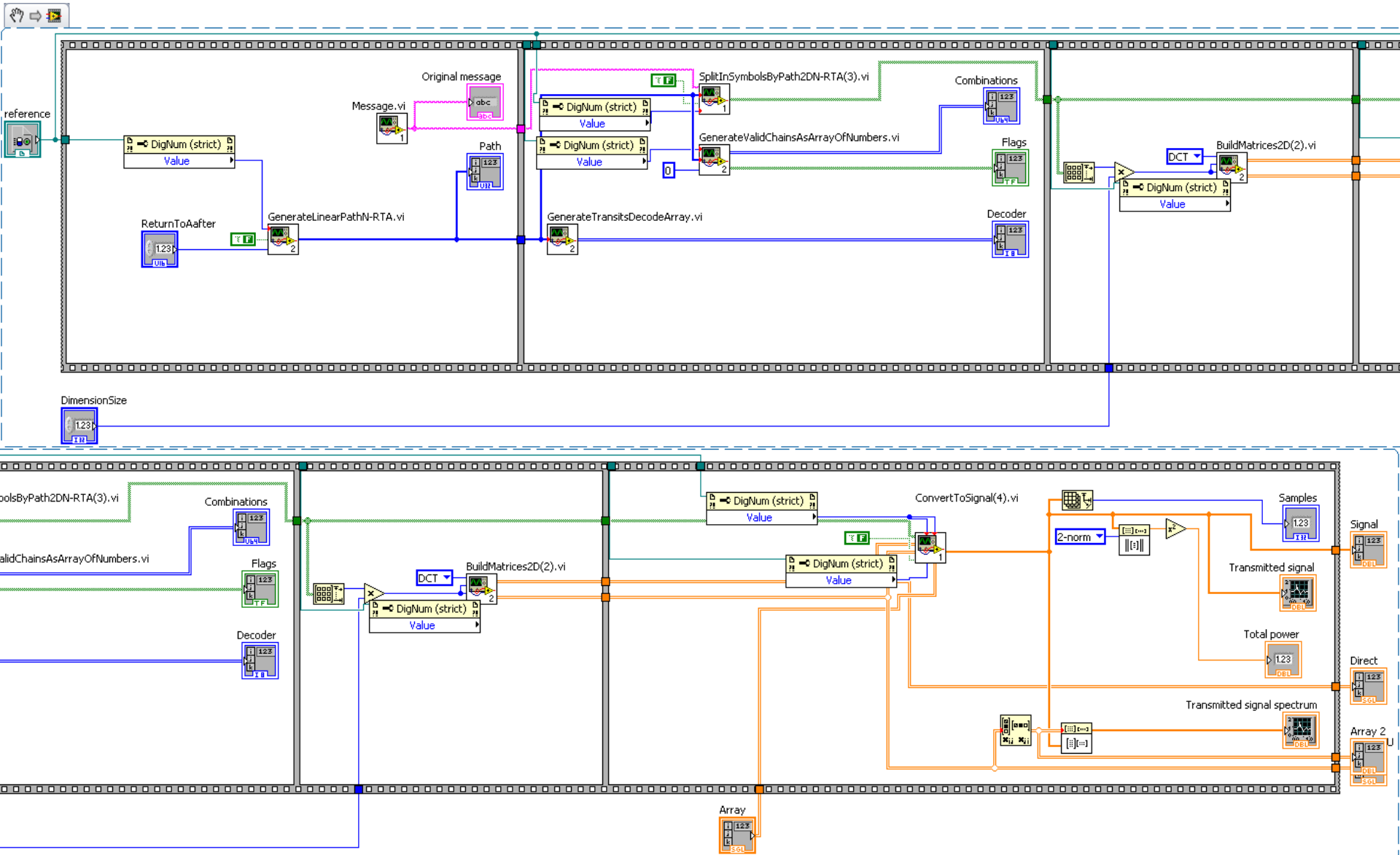
Flags: [Visual indicator showing flag status]

Decoder: [Grid of decoder output bits]

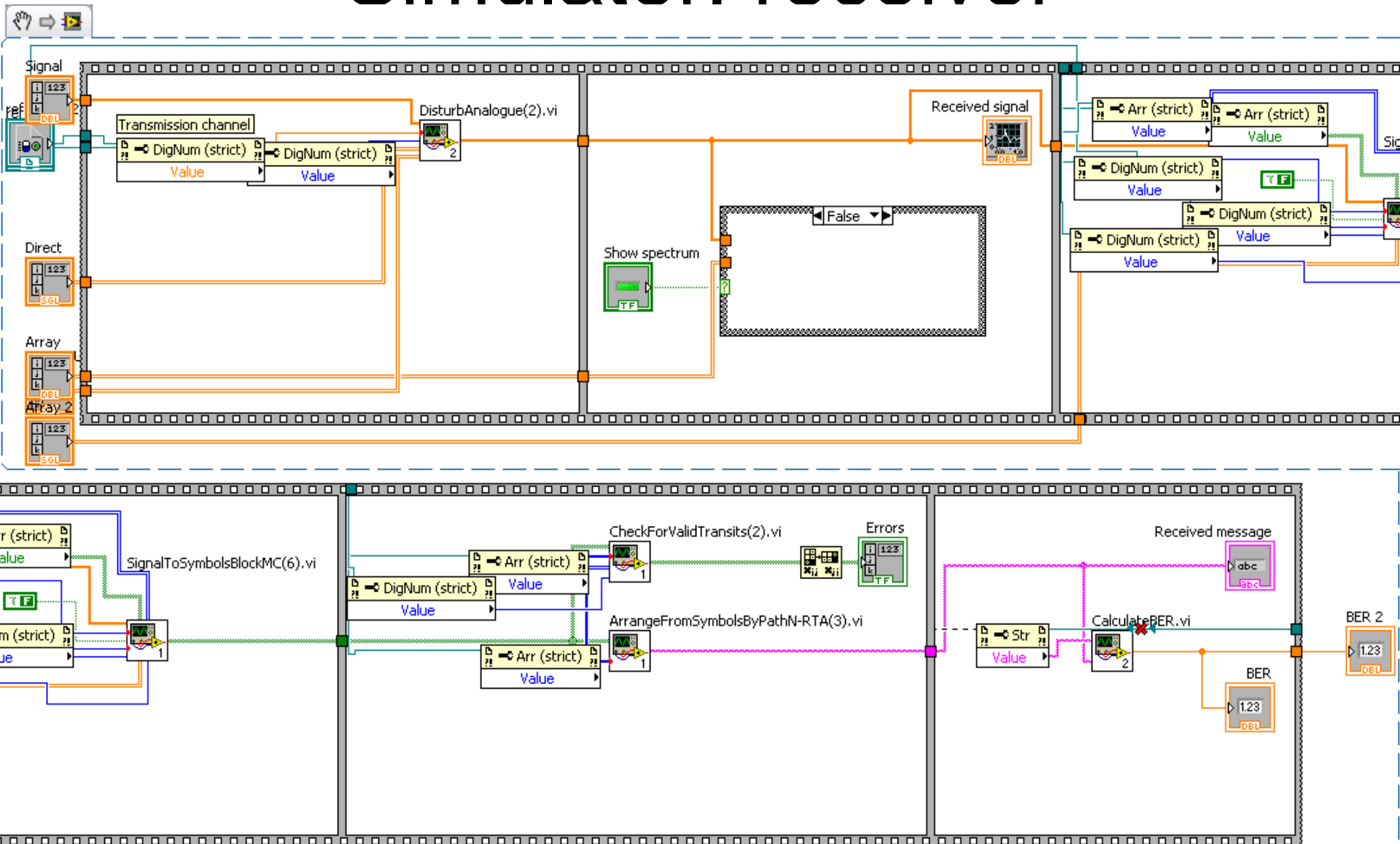
Context Help: Received message. No description available. [Received message (string)]

CSmodulation.lvproj/My Computer

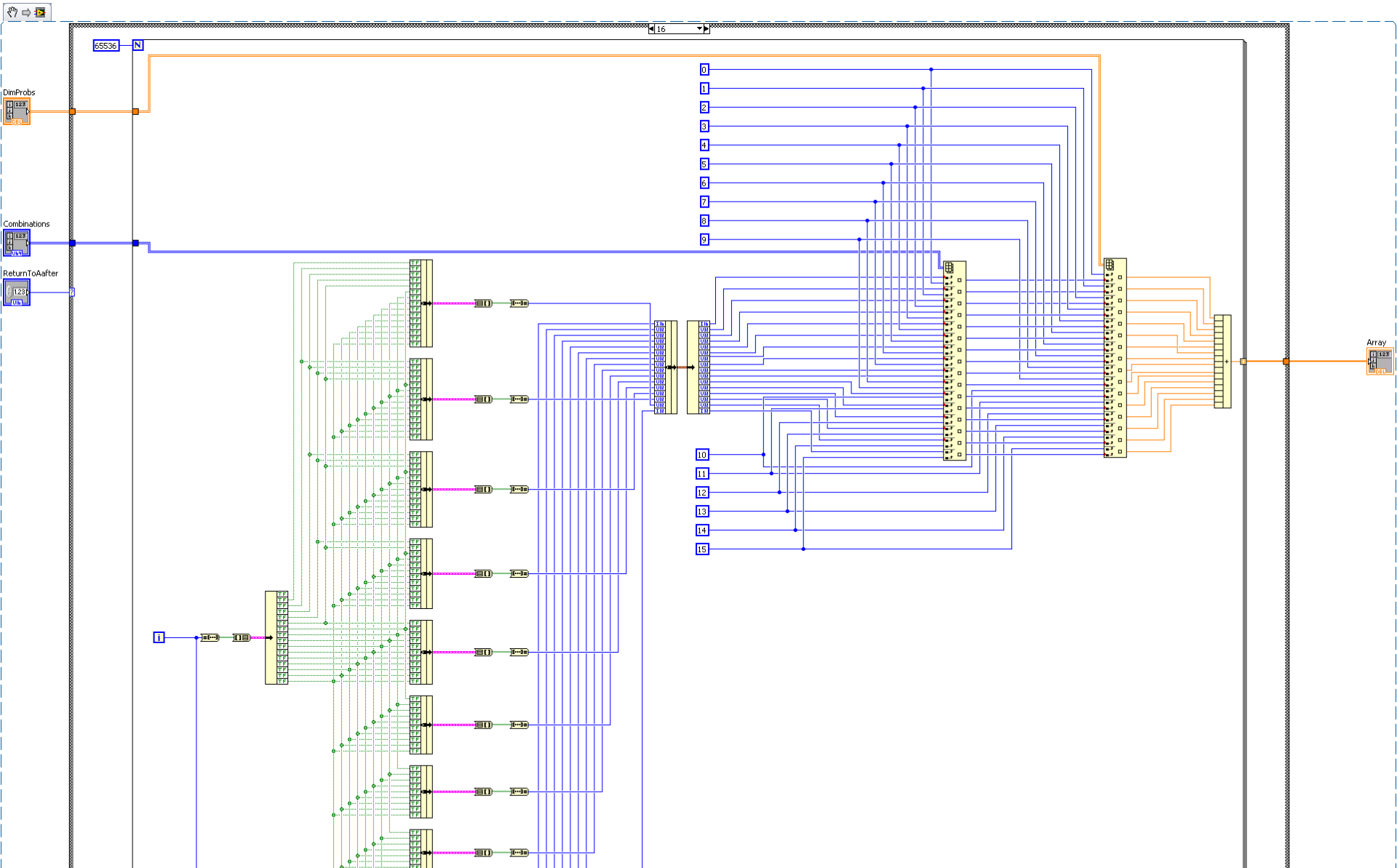
Simulator: transmitter



Simulator: receiver



Implementation specifics

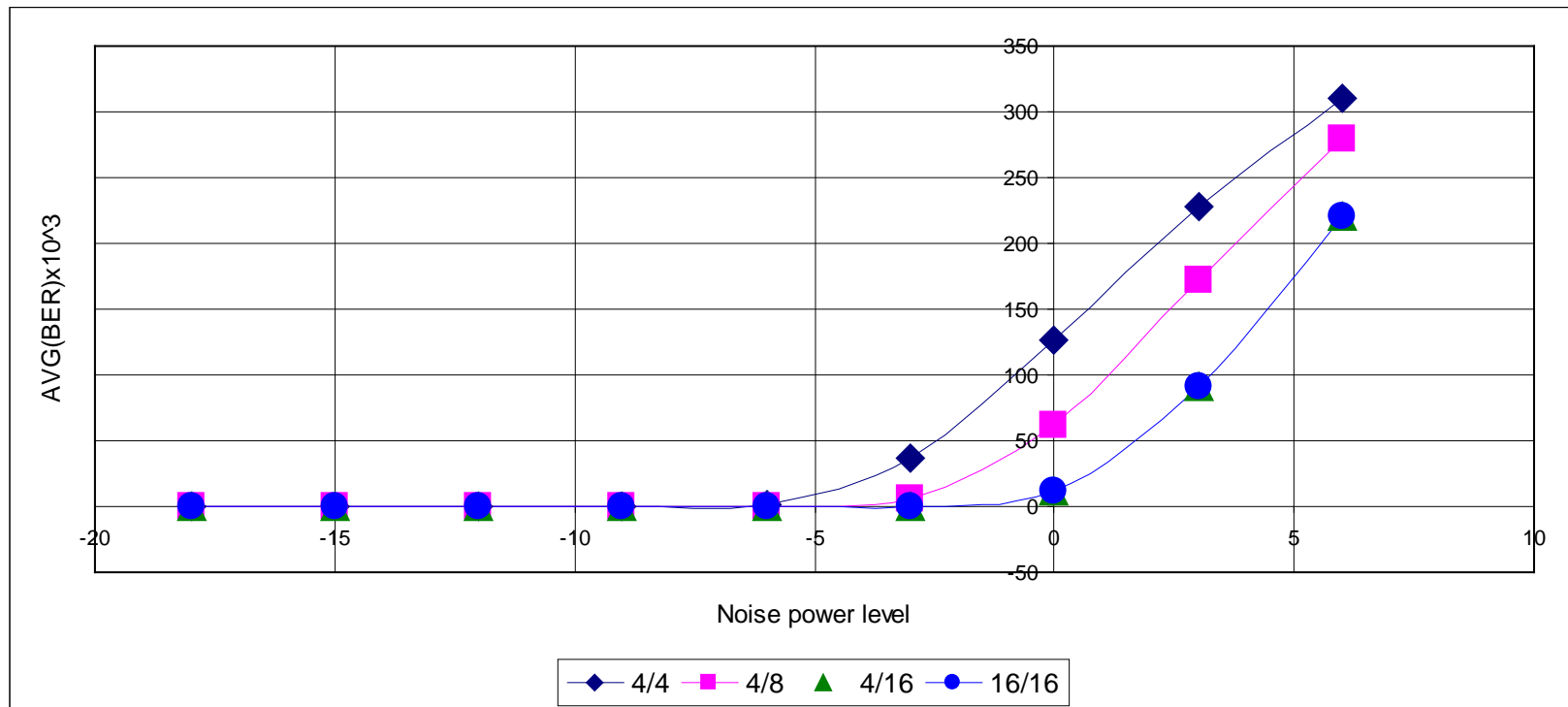


Cases analysed

- 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

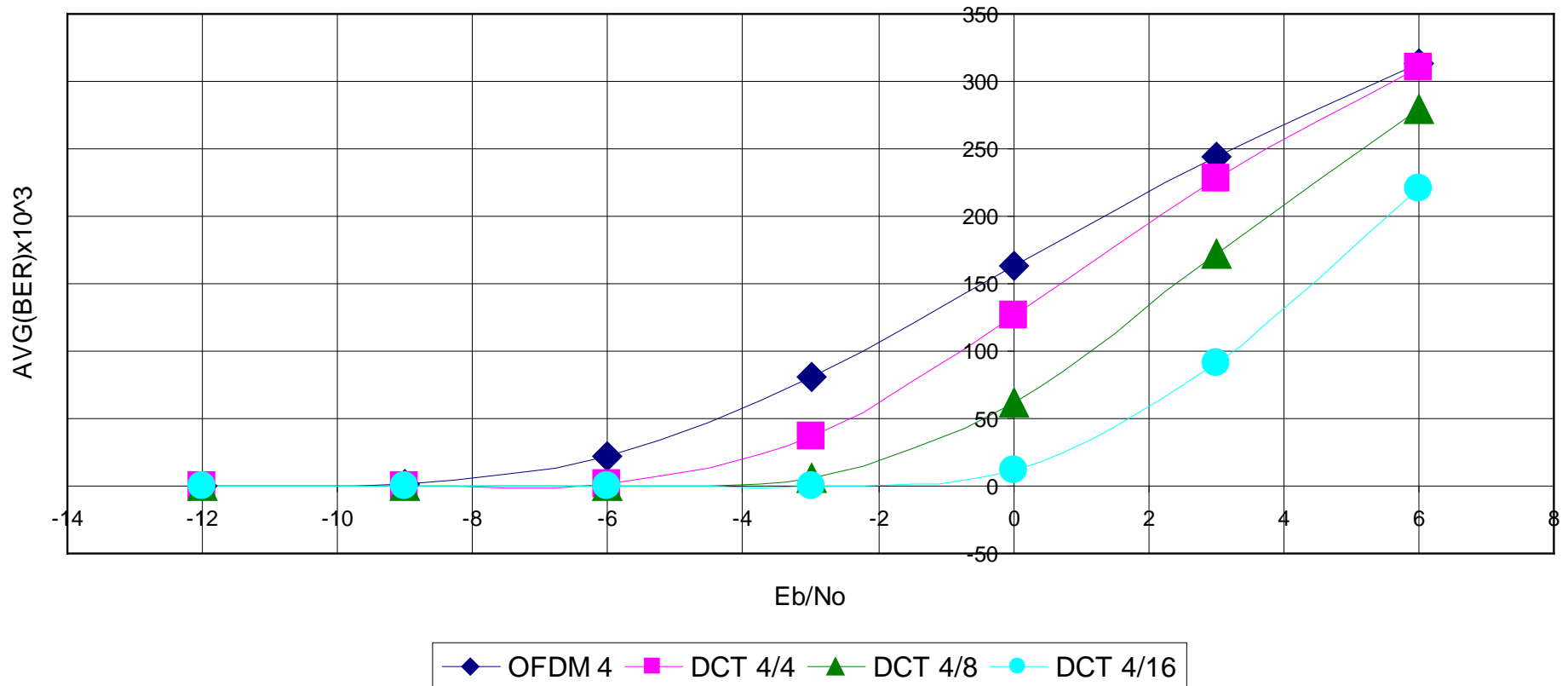
Sample of results

AVG(BER)x10 ³	NPL, dB										Len(msg), samples	Total power
DSize	6	3	0	-3	-6	-9	-12	-15	-18			
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!

