SELEX Elsag

SELEX ELSAG
Secure Networking Solutions
A Finmeccanica Company

Created on 1 June 2011 by the merger of SELEX Communications with Elsag Datamat, an operation also involving SELEX Service Management and Seicos, SELEX Elsag is the Finmeccanica Group company specialised in the design and development of hi-tech systems, products, solutions and services for the following business areas:

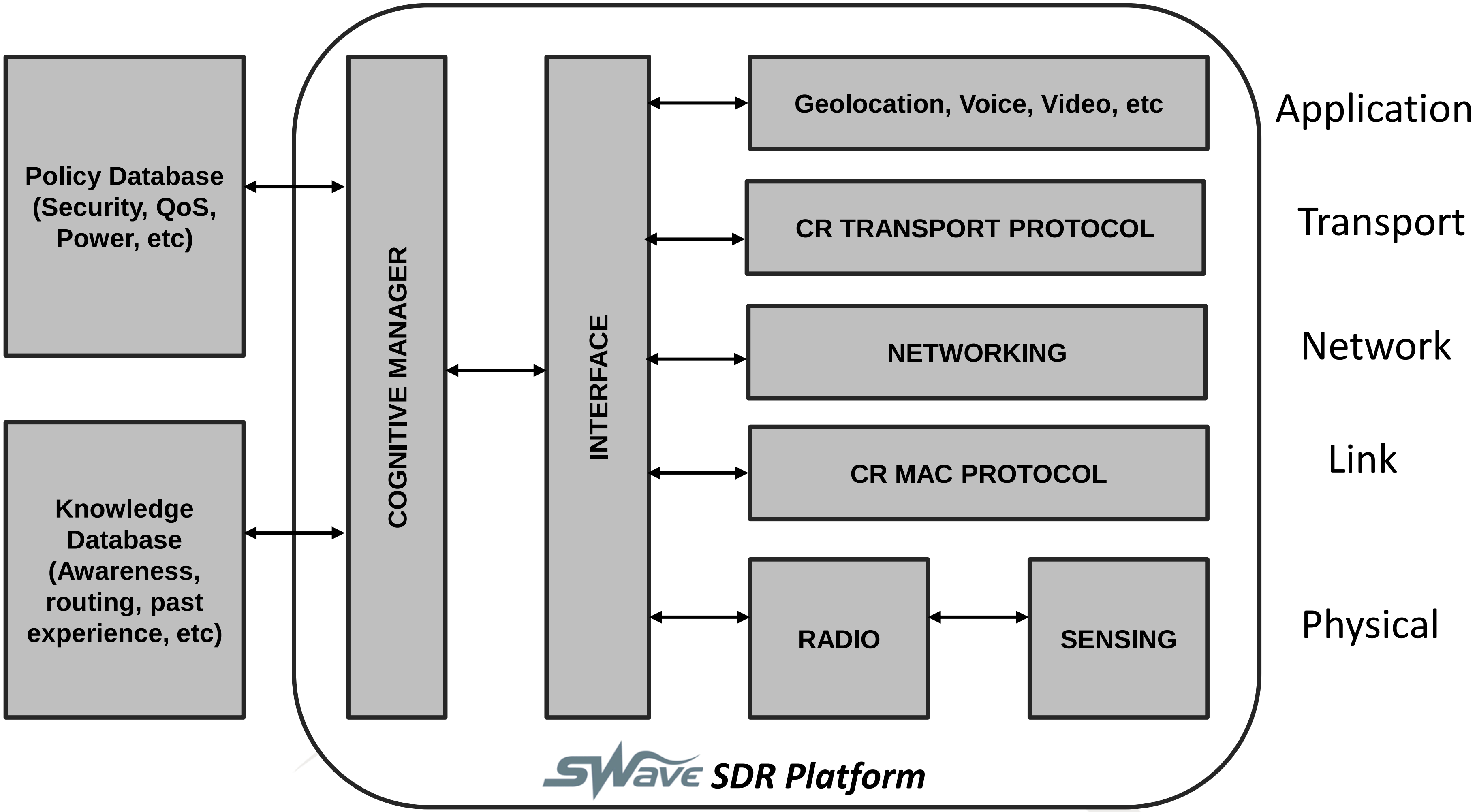
Military BU - SELEX Elsag

SELEX ELSAG
Secure Networking Solutions
A Finmeccanica Company

Integrated communication solutions for strategic and tactical, naval and satellite applications

Land Electronic Warfare	Electronic Warfare solutions for the Electronic Attack, Support and Protection components, integrated with communication systems based on the "Connect and Protect" paradigm to guarantee the connectivity of friendly forces and protect them from the threat posed by improvised explosive devices (IEDs)
Digital Legionary	Modular soldier digitalisation systems that improve operating flexibility and effectiveness, as well as delivering superior mobility and survival capacity
Network Enabled Capabilities	New generation communication systems for sea and land platforms, with advanced networking capabilities to allow coalition forces to achieve information superiority in the NEC framework
Tactical communications	Programmable or software-defined radio and satellite systems, with multi-role and multi-mission capabilities, for the digitalisation of modern armed forces in both interforce and coalition scenarios

Possible update of SDR Platforms to COGNITIVE architectures



SELEX ELSAG
Secure Networking Solutions

SELEX Elsag SDR SWave Platforms and Waveform

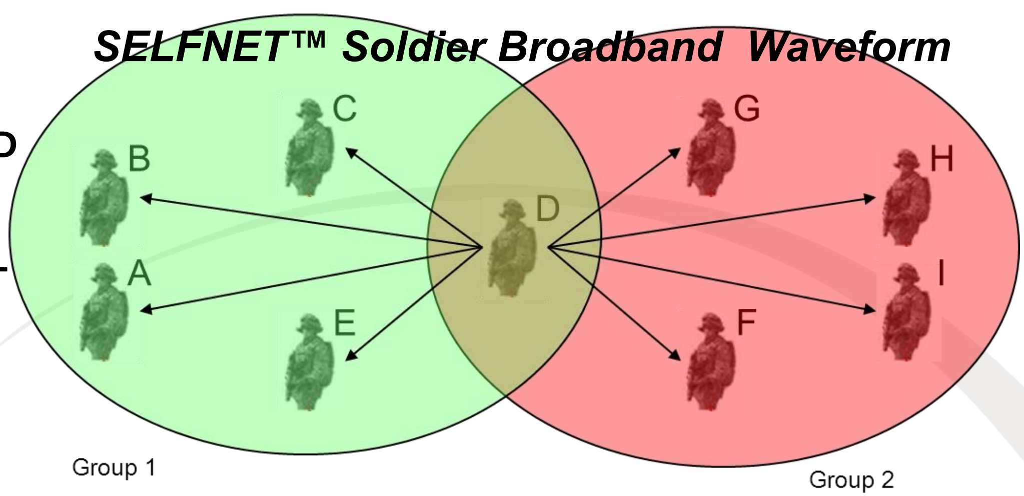
SWave *HANDHELD*

SWave *Vehicular Mono-Channel*

WIDEBAND

QoS

MANET



MULTIHOP

VOICE/DATA SERVICES

SELEX ELSAG
Secure Networking Solutions

PERFORMANCE EVALUATION OF A SPECTRUM-SENSING TECHNIQUE FOR LDACS AND JTIDS COEXISTENCE IN L-BAND

Bartoli G., R. Fantacci, D. Marabissi, L. Micciullo

University of Florence

C. Armani, R. Merlo

SELEX Elsag

TICom

Consorzio per le Tecnologie dell'Informazione e Comunicazione

Outline

- LDACS overview
- JTIDS overview
- Preliminary interference analysis
- Proposed sensing and mitigation method
- Numerical Results
- Conclusions

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

LDACS overview 1/2

Increasing demand for advanced communication services in civil aviation leads to the need for a new communication system able to support the capacity and security requirements of the air transportation system.

- *SESAR* project (Single European Sky ATM Research) aims to develop a new communication infrastructure to support the air traffic management
  - **L-Band Digital Communication System** (**LDACS**) will provide support for air/ground data link
  - Due to high congestion of the VHF frequencies, LDACS will work on the L-band ([960-1213] MHz)
  - Spectral compatibility with other legacy systems operating in L-band needs to be addressed →***JTIDS***

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

LDACS overview 2/2

Two options are currently under consideration:

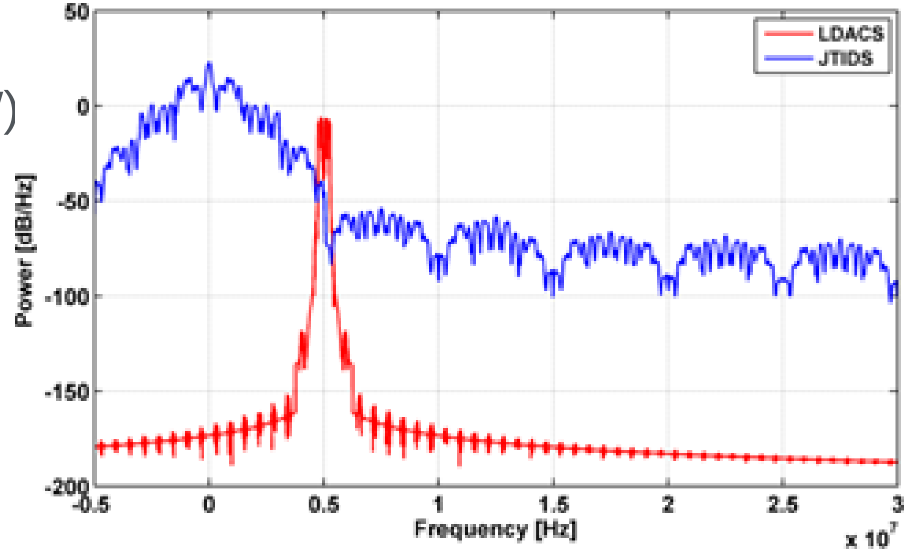
- **LDACS1**
  - FDD: flexible frequency allocation
  - Orthogonal Frequency Division Multiplex (OFDM): allows to contrast multipath effects

- B=498.05 kHz
- N_{sub}=64
- f_s=625 kHz
- T_{symb}=120.0 µs
- QPSK, 16QAM, 64QAM
- Reed Salomon Code (outer)
- Convolutional Code (inner)

- **LDACS2**
  - TDD: flexible resource division
  - Continuos Phase Frequency Shift Keying (CPFSK): minimizes out-of-band emissions

JTIDS oveview

- *Joint Tactical Information Distribution System* (JTIDS) is a military system used for several purposes.
  - ➢ *High transmitted power* (up to 1000W)
  - ➢ *Impulsive transmission* (6.4 μs)
  - ➢ *Spreaded signal* (3MHz)
  - ➢ *Frequency hopping* (N_{hp}=51)



- JTIDS operates in a large range of frequency band [960 - 1215] MHz, hence interference with LDACS becomes **unavoidable**
- JTIDS interfrence affects all the LDACS bandwidth
- JTIDS interference affects only few samples of the LDACS symbol

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Preliminary Interference Analysis

Preliminary analysis permits to identify the conditions (distance, *d* and frequency offset *Δf*) that allow to LDACS to operate in presence of JTIDS interference.

The <u>interference power level</u> is compared with the maximum tolerable interference power level (i.e. min C/I):

$$I(d,\Delta f) = EIRP - PL(d) + G_{rx} - L_{rx} + OCR(\Delta f) + DC$$

- EIRP is the JTIDS Equivalent Isotropically Radiated Power;
- PL(*d*) is the free space path loss;
- G_{rx} e L_{rx} are the LDACS receiver antenna gain and cable loss, respectively;
- OCR(*Δf*) (Off Channel Rejection) takes into account the ability of the victim receiver to reject the interferer signal.
- DC is a term that takes into account the interferer duty cycle.

Preliminary Interference Analysis Results

Assumptions:
The ratio C/I is fixed to 10 dB and C=receiver sensitivity (worst case)
The JTIDS transmission power is fixed to 1000 W.
TSDF is set to 50% and 5% that represent the maximum and minimum values.

	Scenario	Non Interfering Distance	
		TSDF=50%	TSDF=5%
1	Ground Station to Airborne Aircraft	d > 500km	d > 157km
2	Airborne Aircraft to Airborne Aircraft to	d > 500km	d > 500km
3	Airborne Aircraft to Ground Station	d > 500km	d > 260km
4	Ground Station to Ground Station	d > 500km	d > 500km
5	Aircraft on the Ground to Aircraft on the Ground	d > 26.6km	d > 18.5km
6	Ground Station to Aircraft on the Ground	d > 500km	d > 162km
7	Aircraft on the Ground to Ground Station	d > 46.5km	d > 25.5km

Operational distance: minimum vertical separation of the aircrafts: **300mt**

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Proposed Sensing and Mitigation method

The basic idea is the retransmission of the Packet Data Unit (PDU) when the presence of JTIDS system is detected.

- → The first copy of the packet is *stored and combined* with its retransmission
- → Packet combining is used either to improve *interference detection and signal decoding*.
- → JTIDS and LDACS transmissions are independent processes: even if both the copies of the PDU are affected by JTIDS interference with high probability different portions of the PDU are corrupted

Sensing method 1/2

Spectrum sensing is a well-known topic in *Cognitive Radio*

energy detector: computes the energy of the received samples during a time interval called sensing period and Accuracy of energy detector is proportional to the duration of the sensing period

- In the considered scenario:
  - *There is not a dedicated sensing interval*
  - The goal is to detect *which samples are corrupted* and not only if the interference is present

<u>Modified energy detector</u>

- *sensing period must be limited at W samples defined according to the JTIDS signal duration ($W=T_p/f_s+1$ where f_s* is the sampling frequency and T_p the pulse duration)
- *exploits a sliding window which collects the energy of* ***a part*** *of the received signal*

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Sensing method 2/2

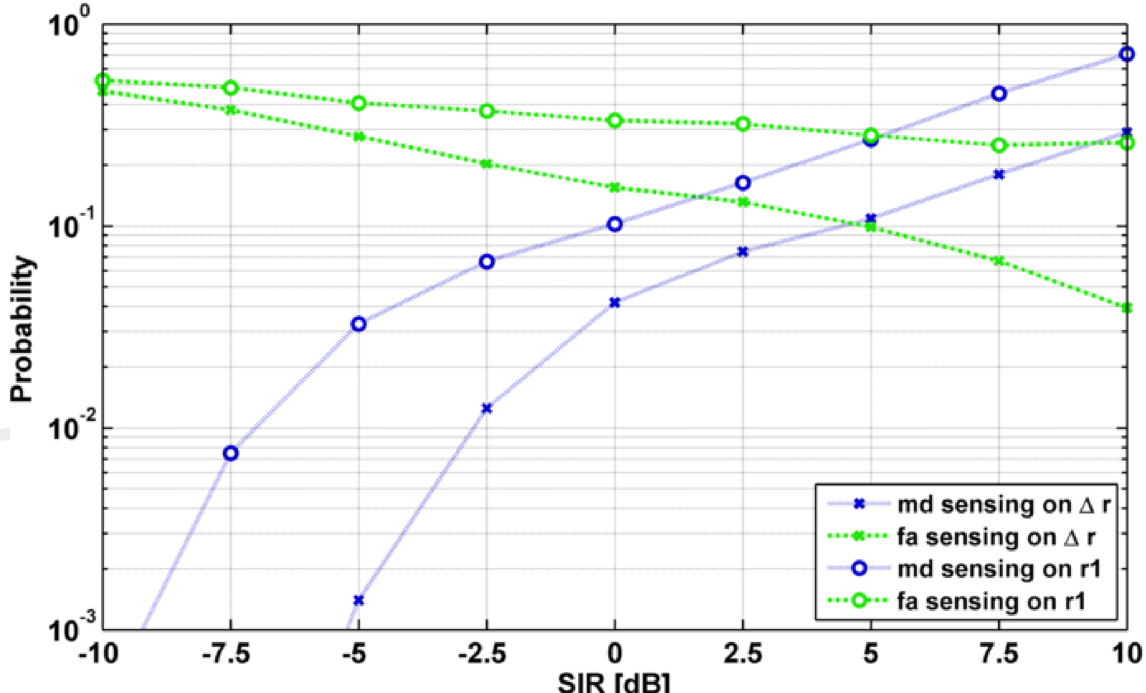
Sensing is performed on the difference between the two packet's replicas

$$\Delta r[i] = r_1[i] - r_2[i]$$

This permits to reduce the false alarm probability due to by the a high peak to average ratio (PAPR) that characterizes the LDACS (i.e. OFDM) signal

$$T_n = \sum_{i=n-\frac{W}{2}}^{n+\frac{W}{2}} a_i \left\| \Delta r[i] \right\|^2$$

M consecutive test statistics (T_n) are observed: if at least *M=L-1* consecutive samples are over the **threshold** we assume the interference is present.



TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Interference mitigation

→ Observing the retransmissions difference is possible to know which samples are affected by interference

→ it is not known if the interference is introduced by the first, $r_1[n]$, or the second $r_2[n]$ copy of the received signal

Indicating n_i as the samples affected by the interference:

1) for each n_i the values of $r_1[n_i]$ and $r_2[n_i]$ are compared: **the maximum is blanked while the minimum is doubled**.
2) the resulting signals are summed together
3) r'[n] is used for data detection

$$r'[n] = \begin{cases} r_1[n] + r_2[n] & if \quad n \neq n_i \quad \forall i \\ 2r_1[n] & if \quad r_1[n] < r_2[n] \quad and \quad n = n_i \\ 2r_2[n] & if \quad r_2[n] < r_1[n] \quad and \quad n = n_i \end{cases}$$

TICom

Consorzio per le Tecnologie dell'Informazione e Comunicazione

Working Hypotesis

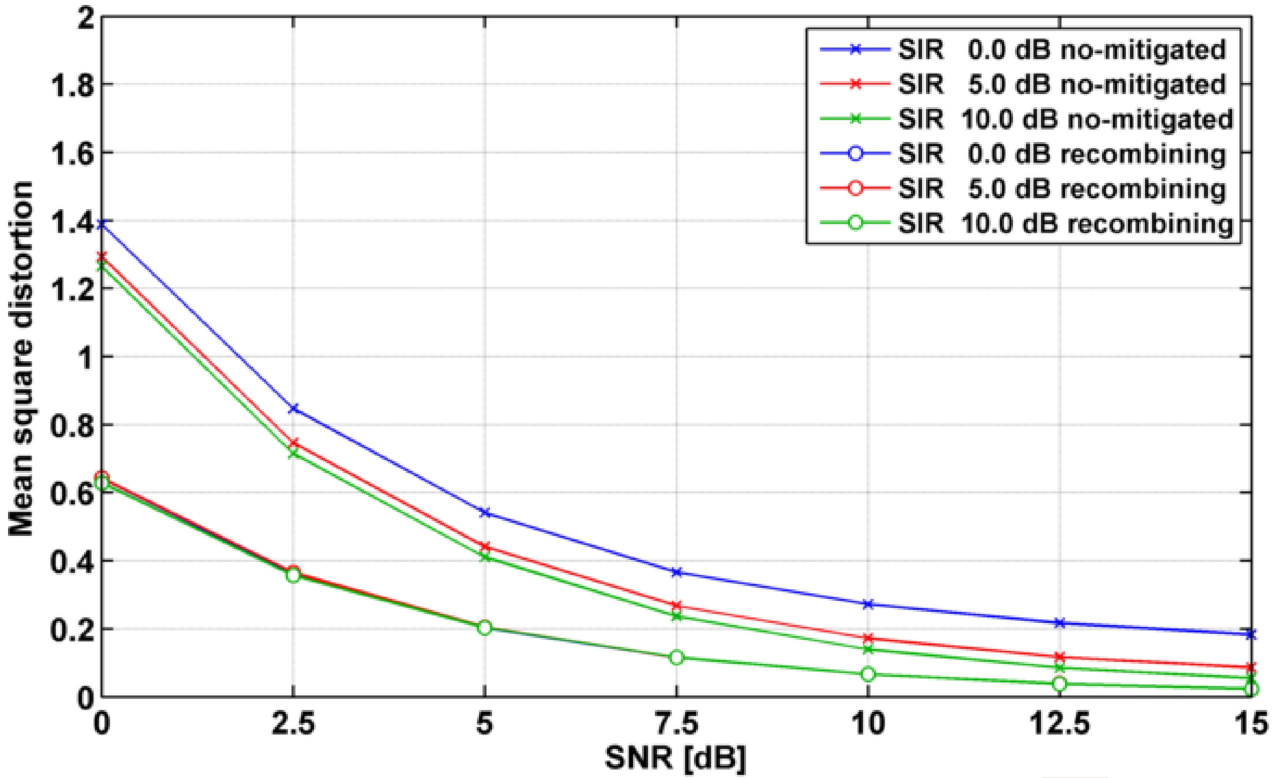
- LDACS modulation scheme: QPSK
- LDACS coding scheme: RSC – Interleaver – CC 1/2
- JTIDS TSDF = 50%
- Only one JTIDS hopping frequency interfers with LDACS system
- SIR values: 0, 5, 10 dB
- Ricean fading channels with K factor equal to 4 dB

TI*Com*
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Numerical results

D mean square distortion of the signal

$$D = \frac{1}{P}\sum_{p=0}^{P-1}\left| r'[p] - s[p] \right|^2$$

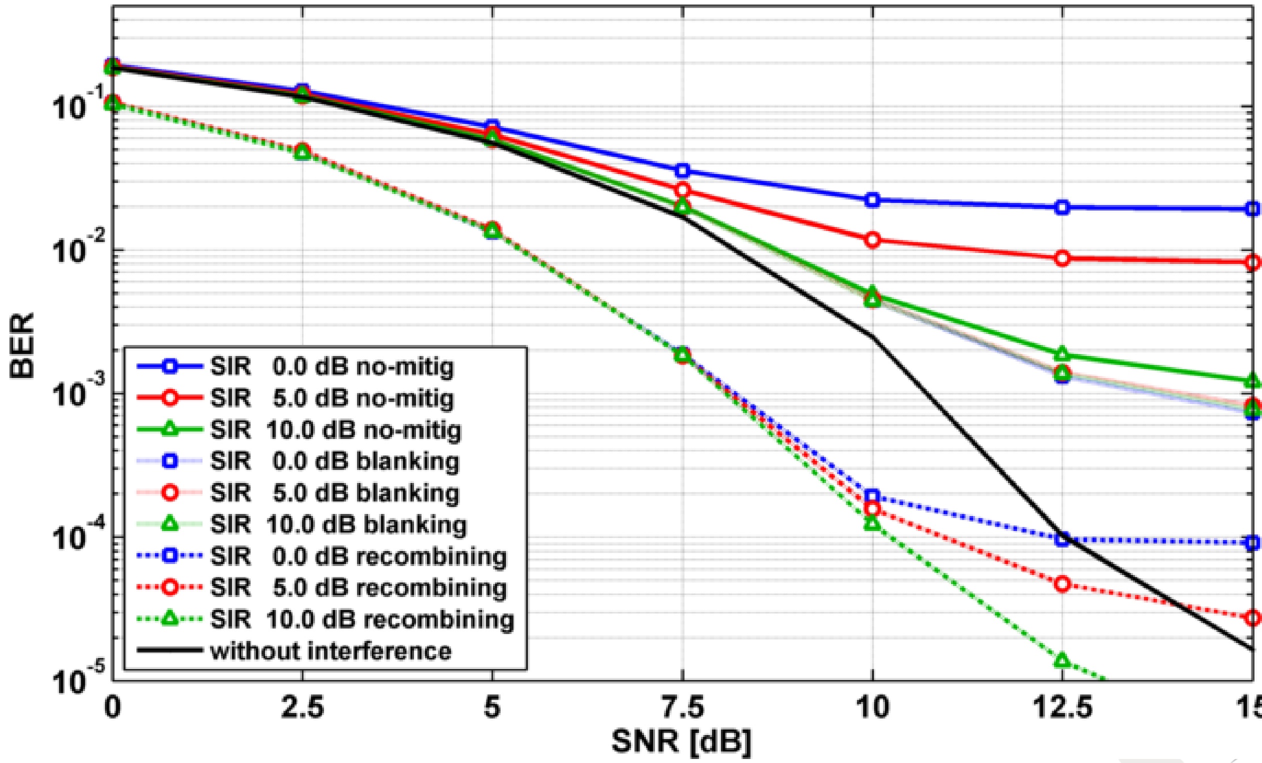


Consorzio per le Tecnologie dell'Informazione e Comunicazione

Numerical results

Bit Error Rate without channel coding:

- The mitigation technique permits to reduce the BER even if compared with traditional blancking technique
- A *floor* effect is present for high SRN due to the residual interefence
- For low SNR a 3dB gain due to soft comibining is introduced

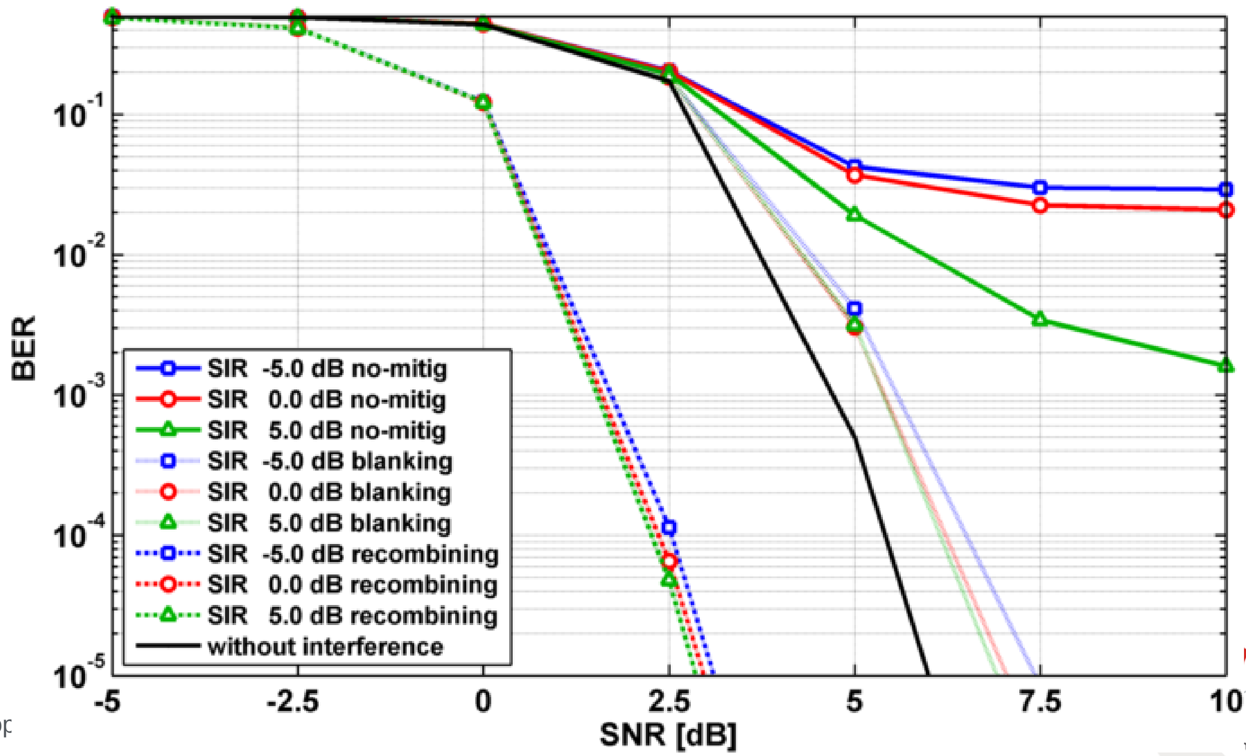


TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione

Numerical results

Bit Error Rate with channel coding:

- The mitigation technique permits to activate the *coding gain*
- *Floor* effect is completely removed
- Interference is completely removed
- A 3dB gain due to soft comibining is introduced respect the No-interference case
- Additional 1 dB gain in introduced respect traditional blanking technique



TICom
nsorzio per le Tecnologie dell'Informazione e Comunicazione

Conclusions

- Future LDACS systems for air/ground communications will work on L-Bands
- Coexistence with JTIDS system has been considered and evaluated
- An Interference Sensing and Mitigation technique has been proposed:
    - It is based on signal retransmission and packet combining
    - Sensing capabilities of the modified energy detector are improved
    - The mitigation scheme is able to reject the interference and a 3dB gain is introduced due to the packet combining
    - An additional 1dB gain is introduced respect the blanking technique.

TICom
Consorzio per le Tecnologie dell'Informazione e Comunicazione