UNIVERSITY of SOUTH CAROLINA
Department of Electrical Engineering

SOFTWARE DEFINED RADIOS AS COGNITIVE RELAYS FOR SATELLITE GROUND STATIONS INCURRING TERRESTRIAL INTERFERENCE

Nozhan Hosseini
David W. Matolak

IEEE CCAA

27-28 June 2017

UNIVERSITY OF
SOUTH CAROLINA

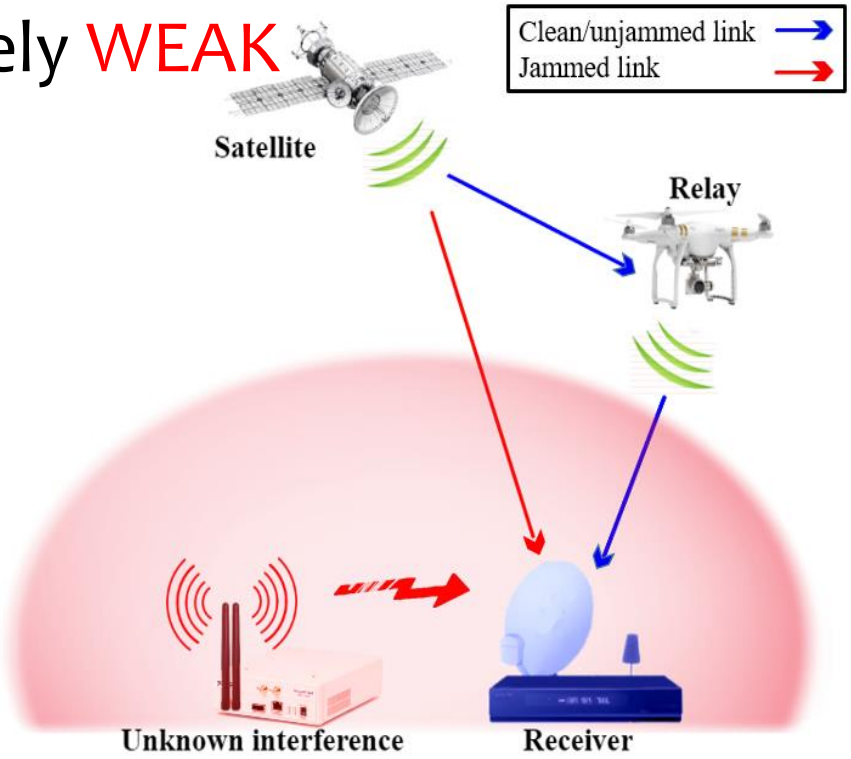
Outline

- Introduction & Motivation
- Main contributions
- Proposed system
  - Software Defined Radios
  - Receiver design
  - Interference
  - Relay Design
- Experimental Results
- Conclusion & Future work

Introduction & Motivation

Issue: satellite signals relatively WEAK

Problem: small amount of interference can degrade performance & potentially deny service to terrestrial terminal



Solution: new entities, e.g., unmanned aerial vehicles (UAVs, or drones) can be used to assist such corrupted links (No modification or reconfiguration to the ground or satellite)

Main Contributions

- Design of most parts of real transmitter-relay-receiver combination through GNU Radio flow graphs & SDRs; close to theoretical performance
- Demonstration of significant suppression of interference & improved ground station satellite signal quality
- Example measured data for 2 relaying methods, yielding useful cognitive relay design information

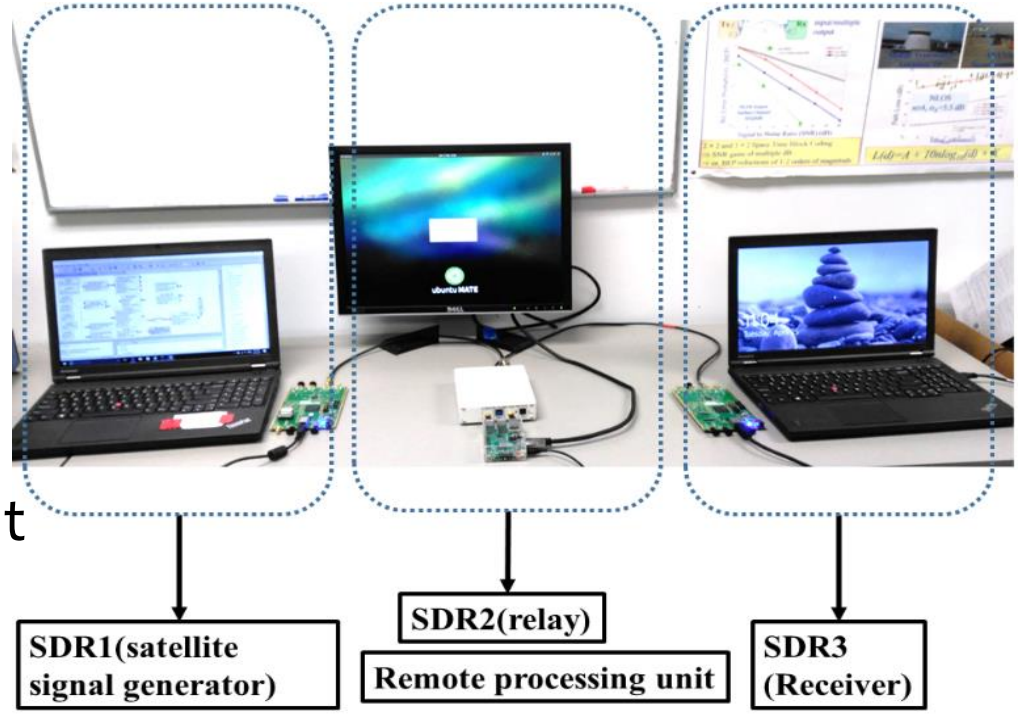
Ettus Research™
A National Instruments Company

MATLAB

GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

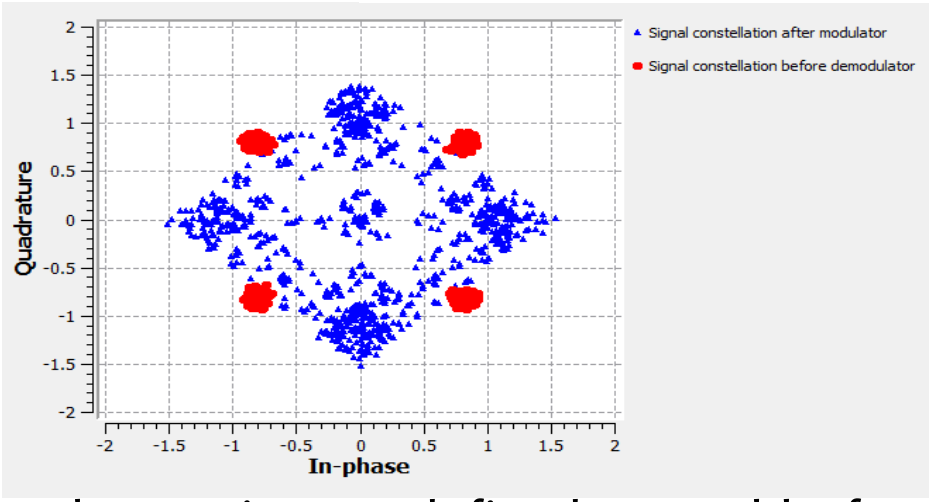
Proposed System

- Stable (“clear sky”) conditions
- No other impairments (e.g., no multipath)
- No antenna misalignment or feeder losses
- Contains three SDRs, working as transmitter, relay, & receiver



Proposed System (2)

Software Defined Radios (SDRs): Flexible modern radios that are reprogrammable or reconfigurable, e.g., Universal Software Radio Peripheral (USRP) is a well-known SDR in the market



Receiver Design

- Timing & phase recovery
- Distortion correction
- Demodulation
- Post processing step extracts packets using predefined preamble for detection & BER measurements

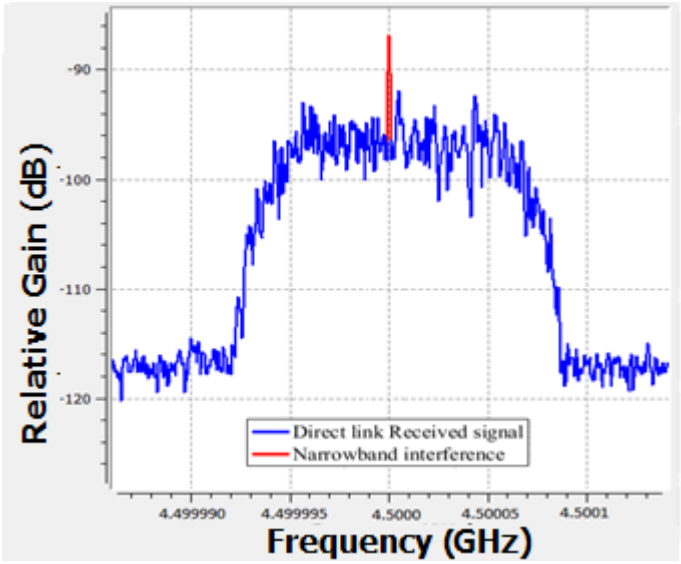
Proposed System (3)

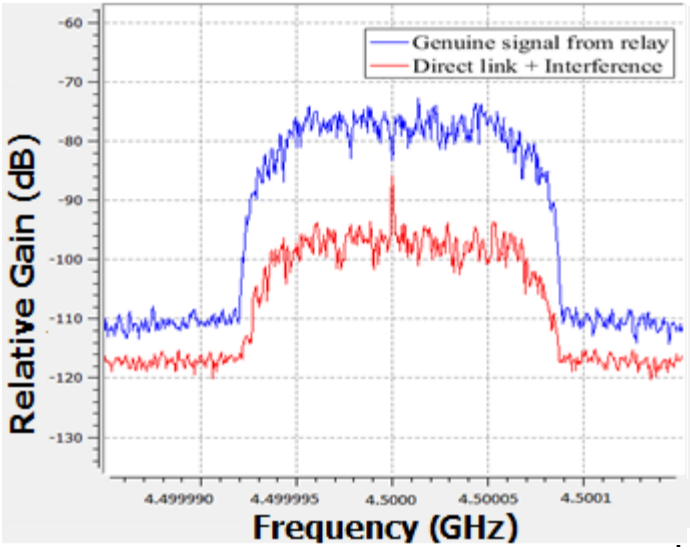
- Interference is narrowband (sinusoidal) interferer
- From jammer located close to ground station
- Since satellite antennas directional, simulate low power interference received through ground station antenna sidelobes

Relay Design

1. Amplify & Forward: relays amplify received signal and retransmits to destination w/o further processing
2. Decode &Forward: demodulates received signal, re-encodes and modulates, then transmits to destination

- Disadvantages
  - 1. Noise
  - 2. Complexity and processing

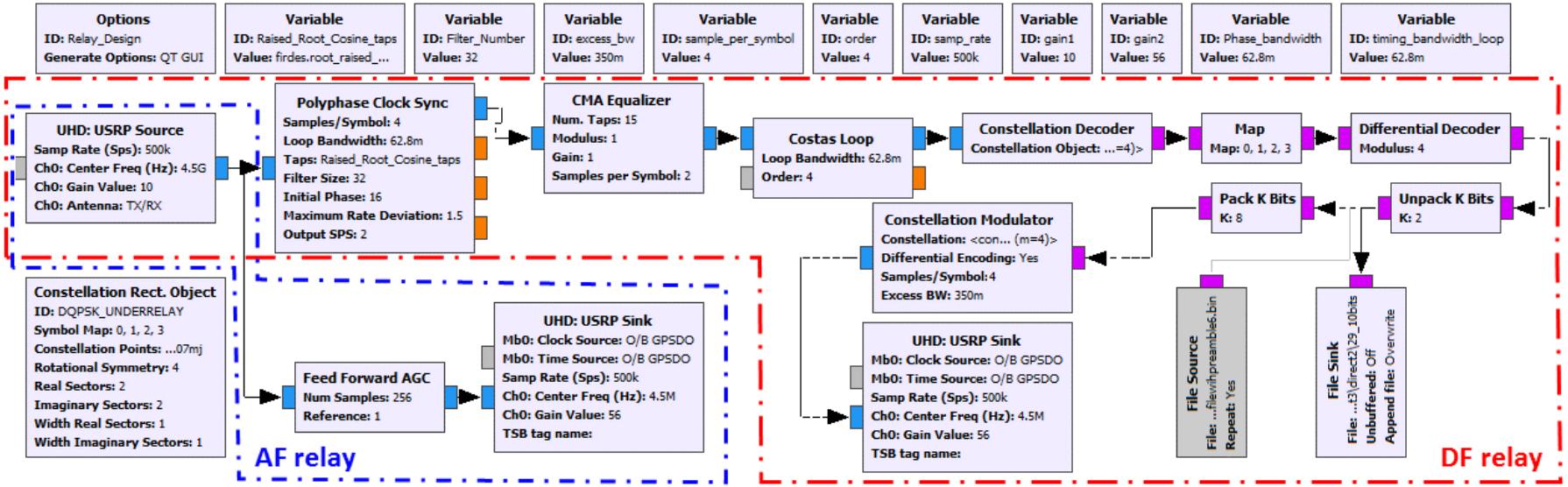




Proposed System (4)

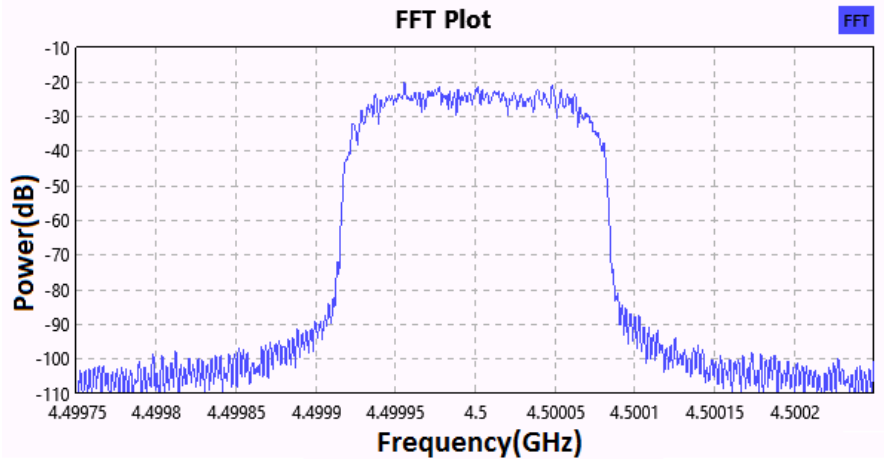
Relay Design Block Diagrams

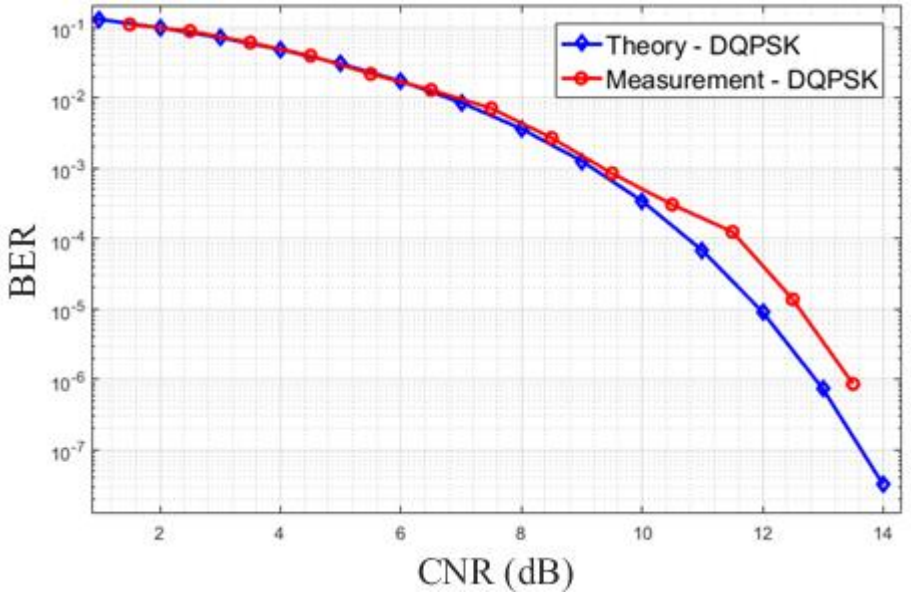
1. Amplify & Forward: relays amplify received signal and retransmits to destination w/o further processing
2. Decode &Forward: demodulates received signal, re-encodes and modulates, then transmits to destination



Experimental Results

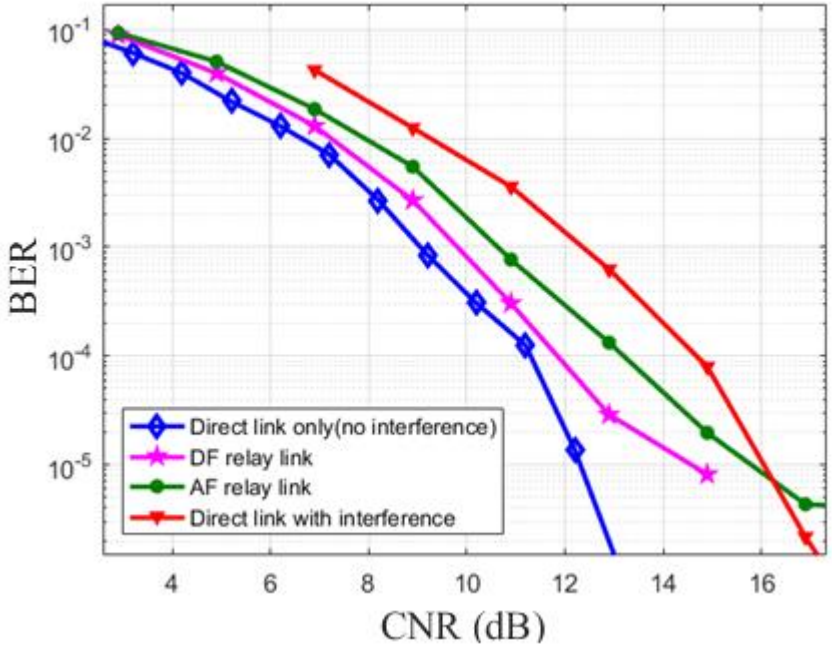
- Gradually increase signal power & measure BER & packet success rate
- Performance follows theoretical curve w/<1 dB implementation loss at higher CNRs down to BERs of 10^{-6}

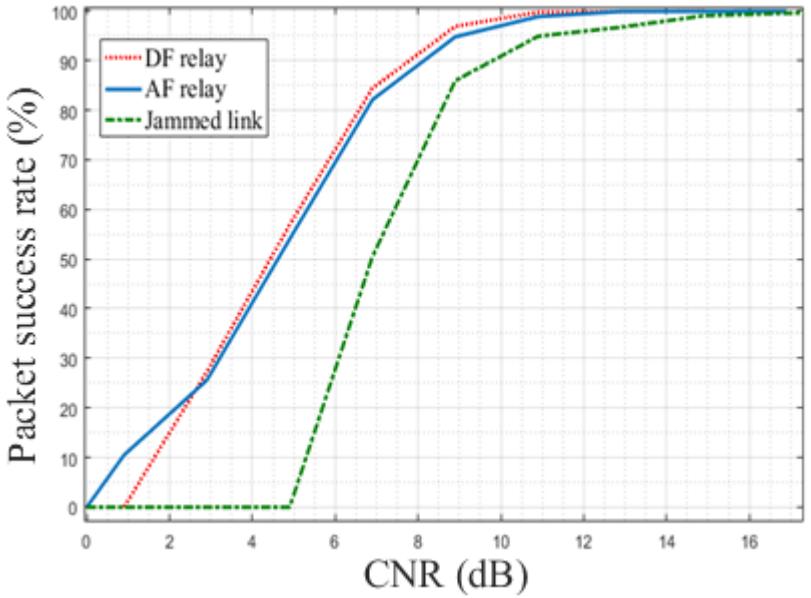




Experimental Results (2)

- Results in presence of interference, w/2 different relaying modes
- Use of relay can substantially improve performance, especially for DF technique
- AF technique advantageous at very low CNRs
- In different applications, relay could select method based on CNR, packet delivery rate, delay and hardware processing capability.





Conclusion & Future Work

- Relay can offer significant performance improvement in presence of interference
  - Packet success rate from 0 to >60% or 60% to 90%...
  - BER reduced by order of magnitude
- AF relaying method worse than DF relaying (AF approach amplifies noise in already weak signal)
- Future work
  - Vary SIR
  - Evaluate for broadband interferers of various types
  - Configure small UAVs to conduct proof-of-concept experiments for satellite signal relaying schemes

Questions ?


3240HD
Optus C1 Sat Found
TP:11928V30000
Strength
99%
Quality
91%
MENU
RETURN
OK
ClearSat
© Copyright TravelSat Australia

Key References

1. L. Grego, "A history of anti-satellite programs," Union of Concerned Scientists,http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nwgs/a-history-of-ASAT-programs_lo-res.pdf, 2012.
2. C. Chang, "DSN Telecommunications Link Design Handbook." DSN Document No. 810–005, Rev. E (2015): 373, 2015.
3. D. Roddy, Satellite Communications, McGraw-Hill, 2006.
4. G. Cuypers, "Noise in satellite links," Belgian Microwave roundtable, 2001.
5. H. Yu, "Performance of cooperative relaying systems with co-channel interference," Doctoral dissertation, Georgia Institute of Technology, Atlanta, GA, 2012.
6. D. Mulally, D. Lefevre, "A comparison of digital modulation methods for small satellite data links," 1991
7. M. Brown, "Guided Tutorial PSK Demodulation," GNU Radio, 8 Mar. 2017,https://wiki.gnuradio.org/index.php/Guided_Tutorial_PSK_Demodulation, 12 Apr. 2017.
8. National Instruments, "DEVICE SPECIFICATIONS NI USRP-2901" datasheet, August 2015.