Program Review:
Telecommunications and
Telemetering Research

Stephen Horan
Director, Telecommunications Program

March 11, 1997
Program Overview
Program Overview

- Topics
  - Program Background
  - Telemetering and Telecommunications
  - NMSU Background
  - Faculty & Staff
  - Facilities
  - Review Program
ABET-accredited College of Engineering
- Enrollment = 14748 students

Statistics (Fall 1996):

- Carnegie-I Research University
- Federally-designated Minority University
- Space Grant University

NMU is the Land Grant University and

NMU Background
60% Other
34% Hispanic
1% American Oriental
3% American Indian
2% African American

Student Ethnicity

NMU Background
Program Overview

M.S.E.E. and Ph.D. degree programs
Communications, Telecommunications Systems
(Channeled Source), Satellite
Theory, Digital Communications, Coding
Graduate-Level courses in Communications
Senior-Level courses in Analog & Digital
Telecommunications Program
Telecommunications Program
Research Programs with

- degrees awarded each year
- Average 5-6 MSE, 2 Ph.D.
- Full-time \& part-time students, off-campus

NASA Space Grant, ACTS Propagation

- NASA (Telemetry \& Telecommunication, Experiment)
Telecommunications by the IFT

Designated Center of Excellence in Telecommunications funded by IFT, State of New Mexico, and industry

Chair Professorship in Telecommunications

Research Programs (cont.)

Telecommunications Program
Grant History
Faculty & Staff

- Faculty
  - Stephen Horan, Director
  - William Ryan, Associate Director
  - Sheila Horan
  - Phillip DeLeon
  - James LeBlanc
  - Thomas Shay
- 10 Graduate Students
- 4 Undergraduates

Students

- Lawrence Alvarez, Technician
- Jenise Apodaca, Secretary

Staff

Faculty & Staff
- Technician
- Secretary
- Director's Office
- Research Laboratory
- Telemeasuring Center is a central suite

- Student Offices in Thomas & Brown Hall
- Faculty Offices in Thomas & Brown Hall
- Goddard Hall

Facilities
Department

Hall (present Engineering Technology Program) to take over the majority of Goddard – Telemeasuring and Telecommunications

Future (hopefully)

– Software simulation area

– Hardware development and testing area

Laboratory

Facilities
- radio equipment
- Mathlab
- Satellite Tool Kit
- Labview
- 5 PCS

Laboratory communications and signal processing
Presently developing IFT-funded academic facilities
Program Overview

12:00-1:30 - Lunch

1:45-2:30 - Coding

8:30-9:00 - Introductions

Small Group Discussion

9:00-9:30 - Program Overview

10:30-10:45 - Break

10:45-12:00 - Bandwidth-Efficient Modulation Techniques

10:45-12:00 - Bandwidth-Efficient Modulation Techniques

1:15-4:00 - Tours & Break

3:00-3:15 - Break

3:15-4:00 - Tours & Demonstrations

4:00-5:00 - Wrap-up

5:00-6:00 - Adjoin

Review

Program Overview
Small Satellite Technology

Thomas Shay
Stephen Horan, Philip Delcon, and

Small Satellite Technology
Small Satellite Access of the Space Network

- Future Plans
- Plans for Next Year
- Current Year Highlights
- Activities
- Purpose

Topics
Priority users are being supported — assist users in gaining access when high-system design — reduce costs associated with communications stations services rather than proprietary ground utilizing the SN for communications

To assist the small satellite community in

Purpose
Spacecraft Testing – testing communications concepts with on-orbit spacecraft testing

Spacecraft Testing – evaluation of communications performance

Orbital Access •

Orbital Access can access a TDRS user satellite can access a TDRS

Predicting when a fixed antenna system on a

Activities
NMSS
- Develop RF satellite simulation tested from
- RF tested
- advanced DSP concepts
- Develop concept for Doppler tracking using
- might be scheduled
- Develop concept for how on-demand services
- DADMA

Activities
throughput

Use SNUG Rev. 7 data to evaluate data

Added TRS-Z to coverage predictions

The previous years

methodology from "home-brew" simulations of

day period using Satellite Tool Kit to improve

looked at 600 km - 1200 km orbits over a 30-

Orbital Access

Current Year Highlights
Figure 1: Simulated 24-hour ground track for spinning-satellite concept with the Space Net.

Orbital Access
Orbital Access - 28.5 deg.

March 11, 1997
Orbital Access - sun synch.
pattern gain
predicted antenna performance due to space loss and
emulated orbital contact
Used STK to simulate passes (50 minutes simulated)
minutes were observed, 50 minutes simulated
pointed at a TDRS for up to 50 minutes (30
found initially, pointed satellites can remain
6 passes used in May 1996

EVE Testing

Current Year Highlights
EVE Testing
Relative Attenuation (dB)

Time (UT)

15.2 15.3 15.4 15.5 15.6 15.7

Measured vs. Predicted

E U V E T e s t i n g
accomplished

WSC beam-forming subsystem might be

- Begun investigation of how the interface to the

in the carrier recovery subsystem

- Begun work on Doppler tracking methodology

- Presented baseline approach at the International

  Conference on I/O Engineering

- DAMA Approach

Current Year Highlights
design

to insure compatibility of the concept and
– began discussions with engineering staff at

DG I Mode 2 transmission

– helical antenna

S-Band Transmission

portion of the system
– began development of requirements for NMU

RF Tested

Current Year Highlights
Preliminary Plans for Next Year

- If found, conduct experiment EV/E-type again
- Satellite
- Working with NASA to identify candidate
- Scenario with orbiting satellite
- Would like to re-try fixed-antenna pointing

Follow-on Spacecraft Testing
WSC

Requirements to beam forming subsystem at the

Complete development of interface

Demonstrate its use in the laboratory

Algorithm

Complete development of Doppler tracking

DAMA Development

Plans for Next Year
Prepare for testing –

begin acquisition and installation of equipment

design with engineers who can critically review

complete requirements definition and review –

RF Tested

Plans for Next Year
document and submit to NASA

- Complete Customer Payload Requirements
- Technology development efforts
- Select suite of experiments from current NSUS
- Develop payload concept in detail

Hitchhiker Proposal

Plans for Next Year
Turbo Code test
passive telemetry via laser communications
DAMA request message
non-embedded antenna pointing

Will need to develop requirements for each test communications concepts

Plan to develop a suite of experiments to

Hitchhiker Payload
Future Plans

- WSC to verify concept
- Run test signals from NMSU through TDRS to carrier
- Develop transmitter with "Doppler" offset
- Develop hardware for WSC interface

DAMA Testing
technology development

- Look for potential industry partners for
  
  packet communications

- small satellite communications

- bandwidth-efficient modulation

- turbo codes

- Develop capability to test
  
  RF Testbed

Future Plans
Future Plans

WSMR
Philips Laboratory

demonstrations; so far, we are looking at
develop partners for technology –
develop suite of experiments –
have proposed project accepted by NASA –

Hitchhiker Program •
Laser Com Activity

by T. M. Shay
Relatively low cost ground station receiver using a FDAOF on the ground based operation in full daylight will be possible consumption.

Very lightweight and very low power.

ADVANTAGES
Plans for next year

• Design laboratory demonstration unit.
  (Report April, 98)

• Build and test laboratory demonstration unit.
  (Report July 1, 98)

• Performance and tradeoffs. (Report Sept, 97)

• Simple model to estimate system
<table>
<thead>
<tr>
<th>System Potential Fielded</th>
<th>40</th>
<th>8&quot; x 10&quot;</th>
<th>16 in</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>8&quot; x 10&quot;</td>
<td>16 in</td>
<td>10</td>
</tr>
<tr>
<td>Tracking Scopes Existing System Using Demonstration</td>
<td>45</td>
<td>4&quot; x 4&quot;</td>
<td>1.8 m</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>4&quot; x 4&quot;</td>
<td>1.8 m</td>
<td>10</td>
</tr>
<tr>
<td>Comments MW Laser Power Modulator Diameter Receiver Kbps Data Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OPTICAL COMMUNICATIONS LIGHTWEIGHT LOW DATA RATE**
Satellite Components

Modulated

Return Beam

Incident Beam

Modulator

Cube Corner
LONG TERM PLAN

• Year I. Model performance and lab test.
• Year II. Perform field experiment (1/2 km).
• Year III. Build and test satellite (Needs additional funding).
• Year IV. Fly satellite and test satellite laser (Needs additional funding).
• Year (Needs additional funding).
This work will be completed this year.

begun. This is also on schedule.

Signal Oscillator Designed and testing has

Stark Anomalous Dispersion Optical Filter.

schedule.

Quantum Mechanical Theory Development on

Fast optical logic model.

PROGRESS THIS YEAR
Space & Telecommunications Center
Department of Electrical and Computer Engineering
New Mexico State University

(supported by a Grant from NASA #NAG 5-1491)
Ruben Caballero, Jianping Tao, Josua Purba
Sheila Hora

SATELITE CHANNELS
NON-LINEAR
8PSK SIGNALING OVER
5. Conclusions & Further Work

- Non-Constant Envelope
- End-to-End System Performance
- Power Containment and Spurious Emissions

4. Results for 8PSK Modulation

- End-to-End Functional System Diagram and Description

3. 8PSK Simulations

2. Approach

1. Introduction
- Plot Average Symbol Variance vs. Bandwidth
- 3 - Non-Constant Envelope Measurements
  - BT product selected such that filter ISI loss > 0.4dB
  - Baseband Filter Optimization:
    - BER plotted as function of symbol SNR (Eb/N0)
  - Measure Symbol Error Rate (BER)
- Calculate Utilization Ratio, at -50dB point
- Measure and Plot Power Spectral Density PSD

Measurements:

Block Diagram created on SPW to perform simulations

Software used: SPW on Sun Sparc 10 Unix Station

MATLAB on PC (Windows) and Unix

SATELLITE CHANNELS
- NON-LINEAR
- 8PSK OVER

(2) APPROACH (cont.)
Modulation Schemes

Phase III: End-to-End Performance with different
Phase II: Effect of Spectrum Shaping
Phase I: BW utilization of various modulation schemes

3 Phases

- power efficiency
- space agencies are under constant pressure to reduce costs.
- frequency bands are becoming more and more congested, and

Why this study?

- Interference susceptibility
- spurious emissions; and
- power efficiency;
- BW needed;

(CCSDS Rf of various modulation schemes in:
SFCG-12 (Australia, Nov 92) requested the study and comparison

--- INTRODUCTION ---

(1)
- ESA 10-Watt Solid State Amplifier (SSPA)
- Power Amplifier based on
- BASEband Filters do not include resistive and reactive losses
  - data imbalance = 0.45
  - data assymetry = 2%
  - Data Generator: Ideal and Non-Ideal Data

Transmitting System:

- Carrier Frequency = 0 Hz (BASEband Simulations)
  - Data: NRZ-L
  - Sample Rate = fs = 16 samples/sec
  - Bit Rate = Rb = 1 bps (Rb = Symbol Rate = (1/3) symbols/s)

SPW Simulation Variables:

Satellite Channels
NON-LINEAR
PSK OVER SPW SIMULATIONS

8PSK OVER NON-LINEAR CHANNEL
(3)
a = 1 and 256 taps;
- Square Root Raised Cosine (SRRC)
- Bessel 3rd Order (BT=1,2,3);
- Butterworth 5th Order (BT=1,2,3);

From Phase II:

Baseband Filters:

- Error Rate Estimator.
- Delay and Phase Meter (Synchronization); and
- SRRC matched filter used for non-constant envelope
  - Matched Filter: Sliding Integrator;

Receiving System:

--------------
8PSK OVER NON-LINEAR CHANNEL (cont)
--------------
(3) - SPW SIMULATIONS
SSPA

Pulse Shaping

Filter

$\theta$

$\theta$

modulator

Non-Constant Envelope Pulse

(Ruben/Josua)

\textit{shaped}\ 8-PSK

imbalance & asymmetry

ideal or

Data

NRZ

mapper

Gray Code

Data

NRZ

Data

NRZ

Data

NRZ
SSPA

modulator

Filter

Pulse Shaping

θ

θ

AE

(T40)

Ideal

shaped 8-PSK

Constant Envelope pulse

NRZ

Data

NRZ

Data

NRZ

Data

Mapper

Gray Code

Map to one of eight possible phases

Data

NRZ

Data

NRZ

Data

NRZ

Data
Output of Gray scale mapper
A. Spectrum Analysis

- Filters
  1. None
  2. 5th order butterworth
  3. 3rd Order Bessel
  4. Square Root Raised Cosine ($\alpha = 1$)

- Ideal Data
  $f_s = 13,1072$ Hz
  $R_0 = 256$ Hz

- Random Phase
  $\theta$

- Baseband Filter

- Phase Modulator

- Solid State Power Amplifier

- FFT

- ESPA SSPA

- ESA 10W

- Spectrum Analyzer
  Bartlett Window

- 100 Spectrums Averaged

- 8PSK EFFICIENT MODULATION STUDY OVERVIEW
B. Simulation on Bit Error Rates

- Sliding Receiver
- Synchronizer
- Matched Filter
- Delay & Phase Meter
- Error Rate Estimator
- Random Phase
- Baseband Filter
- Phase Modulator
- SSPA
- AWGN Channel
- +
- Average Symbol Variance vs. Bandwidth

**Non-Constant Envelope**

BER plotted as function of symbol SNR (Eb/N0)

End-to-End Performance:

\[ p = \frac{\text{number of s/c with filtering accommodated in freq. band}}{\text{number of s/c with filtering accommodated in freq. band}} \]

users

- Sideband attenuation avoids interference to adjacent characteristics
- Establishes user spacing based upon modulation

- Band Utilization Ratio
- PSD plots

Power Containment and Spurious Emissions

8PSK Over Non-Linear Channel

Results for 8PSK

Satellite Channels
Non-Linear
8PSK Over
Non-constant envelope 8 PSK Power Spectra Plots
Output from the SSPA after filtering the data

Filter Output from the 5th Order Butterworth Filter, BT=1

Original Data

Constant Envelope 8 PSK Power Spectra Plots
5th Order Butterworth Filter, BT=3

5th Order Butterworth Filter, BT=2

Butterworth Filter, BT=1

Constant envelope 8 PSK
SSPA Power Spectra Plots
3rd Order Bessel Filter, $B_L = 3$

3rd Order Bessel Filter, $B_L = 2$

3rd Order Bessel Filter, $B_L = 1$

Constant envelope 8 PSK SSB Power Spectra Plots
Square Root Raised Cosine Filter, Roll off Factor, α=1

SSPA Output, +/−10dB (Raised Cosine, α=1, Ideal Data)

Constant envelope 8 PSK

SSPA Power Spectra Plots
8PSK Over Non-Linear Channel

RESULTS FOR 8PSK
8PSK Over Non-Linear Channel

Results for 8PSK
3rd Order Bessel Filter: Average Symbol Variance vs BT

Bandwidth-Time Product (BT)

Variance in Degrees

3rd Order Bessel Filter: Average Symbol Variance vs BT

8PSK Over Non-Linear Channel

Results for 8PSK
Zoom of average Symbol Variance vs DT for 3rd Order Bessel Filter

Bandwidth-Time Product (Bt)

Variance in Degrees

3 3.5 4

3.5 2.5 2 1.5 1

0.5 0 0.1

3.5 3

x 10^-6

8PSK over Non-Linear Channel

RESULTS FOR 8PSK
SPC Filter Average Symbol Variance vs Roll-off Factor ($\alpha$)

Results for 8PSK
<table>
<thead>
<tr>
<th>Filter</th>
<th>Type</th>
<th>Non-Coast Envelope</th>
<th>Constant Envelope</th>
<th>Utilization ISI Loss</th>
<th>ISI Loss and Utilization Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>2.00</td>
<td>14.00</td>
</tr>
<tr>
<td>14.4</td>
<td>1.346</td>
<td>0.43</td>
<td>0.29</td>
<td>10.00</td>
<td>9.43</td>
</tr>
<tr>
<td>10.8</td>
<td>BW BT=2.8</td>
<td>1.58</td>
<td>1.186</td>
<td>1.72</td>
<td>BW BT=3</td>
</tr>
<tr>
<td>1.17</td>
<td>Beessel, pt=1</td>
<td>1.44</td>
<td>1.67</td>
<td>11.1</td>
<td>Beessel</td>
</tr>
<tr>
<td>20</td>
<td>BW BT=1</td>
<td>1.15</td>
<td>10.94</td>
<td>7.78</td>
<td>Beessel, pt=2</td>
</tr>
<tr>
<td>28.5</td>
<td>SRRC a=1</td>
<td>0.98</td>
<td>0.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>7.7</td>
<td>Beessel, pt=3</td>
<td>0.29</td>
<td>7.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.8</td>
<td>BW BT=2.8</td>
<td>1.15</td>
<td>10.94</td>
<td>7.78</td>
<td>Beessel, pt=2</td>
</tr>
</tbody>
</table>

ISI Losses and Utilization Ratio
Block Diagram

Over a Non-Linear Satellite Channel
The Implementation of Pulse Shaping on 8-PSK Signaling
Investigate spikes

- Use Equalization to improve BER
- Find a close form equation for different filter orders.
- Implementation in hardware;
- Simulations for higher order of RL
- Obtain better models for High Power Amplifiers

What is next:

- For non-constant envelope: there is a pattern
- BER still not good enough

Constant Envelope 8PSK gives 24 to 48 improvement at RL=1.
Improvement by a factor of 12 to 24 (RL=1) with Filtering 8PSK.

Conclusions:

---

(5) CONCLUSIONS/FURTHER WORK

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Coding Talk Outline

1. Introduction to Turbo Codes
2. On Transparent Turbo Codes
3. Turbo Codes in Pulsed CW RFI
4. High-Rate Turbo Codes
5. WSC1 Turbo Code Test
\[ 2^8 = 101 = 2 \]
\[ 2^8 + 2^8 + 1 = 1111 = 15 \]

Example: Rate \( r = 1/2 \).

**Nonrecursive Convolutional Codes (CC)**
Example: \( G(D) = \binom{D}{0} \)

Remember \( G(D) = \binom{D}{0} \) from non-recursive CC

RECURSIVE SYSTEMATIC CC (RSCC)
TC ENCODER
March 1997

New Mexico State University

Omer Acikel, Ph.D. Student
William E. Ryan, Assistant Professor

ON THE TRANSPARENCY OF TURBO CODES
OUTLINE

I. Introduction to Turbo Codes
II. Application to Turbo Codes
III. Simulation Results
as a result of the ambiguous lock phenomenon of carrier recovery circuits.

The utility of transparent codes -- also called rotationally invariant codes -- arises

A code is transparent if \( u \) \( \leftrightarrow \) \( c \) implies \( u \leftrightarrow c \).

Definition

1. By \( u \leftrightarrow c \) we mean the message word \( u \) is mapped to the codeword \( c \) by the

Notation

1. INTRODUCTION TO TRANSPARENT CODES
number of taps in each of its n generators is odd, i.e., \( \forall i \in \mathbb{N} \), odd.

RESULT: A rate \( \frac{1}{n} \) non-recursive convolutional code is transparent if and only if the

Review of Transparent Non-Recursive Convolutional Codes

These results are due to Prof. Steve Wilson of the University of Virginia

II. APPLICATION TO TURBO CODES
iff the number of nonzero $g_i$ is odd

$\gamma = \gamma' c = 1 + \gamma' c = \gamma c$

\[ \gamma \sum_{i=0}^{\infty} g_i \sum_{w}^{0} + \gamma \sum_{w}^{0} \sum_{i=0}^{\infty} g_i - \gamma n \sum_{w}^{0} \sum_{i=0}^{\infty} g_i (1 + \gamma n) \sum_{w}^{0} = c \]

When $u = 0$, the encoder output is

$\sum_{i=0}^{\infty} \gamma - \gamma n \sum_{w}^{0} = c$

**Proof:** When $u = 0$, the encoder output is
and $W^H$ are odd. $[(Q)p]^H$ are odd.

The code will be quasi-transparent whenever both $W^H$ and $[(Q)p]^H$ are off.

RESULT: A recursive convolutional code cannot be transparent, but can be quasi-transparent.

The Result for Recursive Convolutional Codes (cont'd)
II. APPLICATION TO TURBO CODES (cont.)

Proof: We note that when \( u \) is input:

1. The systematic part of the codeword \( c = [ d | u ] \) is automatically

2. The parity is complemented if and only if \( (s^{k-1}, s^{k-2}, \ldots, s^{k-m}) \) is complemented.

But, \( s^k \) and \( \bar{s}^k \) = \( (s^{k-1}, s^{k-2}, \ldots, s^{k-m}) \) will be complemented, for all \( k \geq 0 \), if:

I. The encoder initialized to \( 0^0 \)

2. \( (D)p \) is odd
\[ l^0_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + l^1_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + 0_n = \]

\[ l^1_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + 1 + l^1_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + 0_n = \]

\[ l^1_p \left( l^1 + l^-s \right) \frac{\mathcal{L}_w}{\mathcal{L}_w} + 1 + 0_n = \]

\[ l^1_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + 0_n = 0_s \]

When \( n \) is input and the encoder is initialized to \( 0^0 \), \( s \), \( l^1 \), \( l^-s \), \( l^1 \) = 1.

\[ l^1_p \frac{\mathcal{L}_w}{\mathcal{L}_w} + 0_n = 0_s \]

Proof of previous bullet: When \( n \) is input,
II. APPLICATION TO TURBO CODES (cont.)

\[ (q_I^p)^{H_w} \text{ is odd} \]

\[ ([q_I^p])^{H_w} \text{ is odd} \]

\[ 0_s = \]

\[ 1 + 0_s = \]
Because turbo codes employ two (or more) recursive convolutional codes, a turbo code also passes-transparent.

II. APPLICATION TO TURBO CODES (cont'd)
\[ \begin{align*}
\text{else} & \quad = 0, \\
\phi_s(1) & = 0.5, \\
\text{else} & \quad = 0,
\end{align*} \]

\[ D1: \phi_s(0) \]

Start in the all-ones state:

account for the 50% chance of looking out of phase and the encoder appearing to

As a result, the constituent decoders must initialize their state probabilities to

\[ \text{out of phase}. \]

\[ c (\text{when locked}) \leftrightarrow c (\text{when locked \( \pm 180^\circ \)}) \leftrightarrow (\text{when locked}) \leftrightarrow (\text{when locked \( \pm 180^\circ \)}) \]

Thus, on channels with ambiguities, the decoder may see the situation

II. Application to Turbo Codes (cont.)
we can expect some degradation relative to the ideal due to decoder's uncertainty in the encoder's initial state.

\[ (s)_{(c)}^N \alpha = (s)_{(c)}^N \beta \]

\[ \text{else } 0 = \]

\[ \text{D2: } c_0^0(s) = 0.5 \text{ for } s = 0 \text{ and } 2^m - 1 \]

II. APPLICATION TO TURBO CODES (cont'd)
Simulation Model

\[(u(t) = 37)_{\text{octal}} = (a)_{\text{octal}} = (a)p\]

Comm., May 1996: Parallel concatenated codes, by S. Benedetto and C. Monzorski, IEEE Trans. A turbo code with WH[n] and WH[\(\text{odd}\)] was selected from Design of Simulation Results

III. Simulation Results
Burst Error Results with the Transparent Code (31',37')
<table>
<thead>
<tr>
<th>Blocks</th>
<th># of Errors</th>
<th>1.97</th>
<th>98716</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>5.63</td>
<td>1.77</td>
<td>89950</td>
</tr>
<tr>
<td>507</td>
<td>5.75</td>
<td>2.31</td>
<td>102801</td>
</tr>
<tr>
<td>500</td>
<td>6.57</td>
<td>2.12</td>
<td>106404</td>
</tr>
<tr>
<td>503</td>
<td>6.22</td>
<td>2.12</td>
<td></td>
</tr>
</tbody>
</table>

For 500 error events, *E_b/N_0=2db*.

*5 iterations, N=1000.*

(31,37) Transparent Code (cont'd) Burst Error Results with The
March 1997

New Mexico State University
William E. Ryan, Assistant Professor

Performance of Turbo Codes in Pulsed CW RFI
Outline

I. RFI Model
   II. Simulation Results
      III. Future Work
otherwise
\[ \hat{r}_2 > r > \hat{r}_1 \quad \text{for} \quad \hat{r}_2 \]

\[ 0 = (\phi + i \omega) = (t) \cdot \hat{v} = (t) \]

where, for CW RFI, \( \hat{v} \) is:

\[ \hat{v} = \frac{2T}{2} \cdot \cos(\omega) \]

Model of turbo-coded BPSK channel in AWGN and RFI

1. RFI Model
where \( \omega \equiv \omega_0 \equiv 0 \text{ and } -2\pi < \omega < 2\pi \) (mod \( \omega \equiv I(0) \)).

\[
\max \left( \frac{2L}{1+\kappa^2}, 0 \right) \sin \frac{2L}{2} \left( \phi + i \omega \right) =
\]

\[
\min \left( \frac{2L}{1+\kappa^2}, 0 \right) \cos \left( \frac{2L}{2} \right) \left( \phi + i \omega \right) \int \frac{2L}{2} \left( \phi + i \omega \right) = \kappa_I
\]

RFI component at sampler output

1. RFI model (cont'd)
4. $\alpha$ is uniformly distributed on the interval $(-\infty, 2\pi / \lambda, 2\pi / \lambda)$

3. Gaussian amplitudes $\mathcal{N}(\mu, \sigma)$

2. Gaussian widths (durations): $\mathcal{N}(\mu, \sigma')$

1. Poisson arrivals $\Leftrightarrow$ Exponential inter-arrival times: $\exp(\lambda)$

RFI Statistics

1. RFI Model (cont'd)
II. SIMULATION RESULTS
II. SIMULATION RESULTS (cont'd)

AWGN baseline: 5 iterations

5 iterations
N=10200
R=1/2

Proposed (31, 33) Turbo Code Performance in AWGN
II. SIMULATION RESULTS (cont'd)

AWGN + RFI (5 iterations):

\[ SIR = -20 \, \text{dB} \]

\[ \frac{\mu_w}{\sigma_w} = \frac{N}{1000} = 10, \quad \sigma_w = \mu_w / 5 = 2 \]

\[ \lambda = 5/10000, 1/10000, 0.2/10000 \]
II. SIMULATION RESULTS (cont'd)

\[ \text{(5) } \varphi = \frac{1}{2}, \quad \Omega = \frac{1}{2}, \quad \mu = 10, \quad \sigma = 1, \quad \text{SIR} = 20 \text{ dB} \]
PERFORMANCE DEGRADATION IS NEGLIGIBLE

AWGN + RFI (5 iterations):
SIR = -20 dB

fix $\lambda = 0.2 / 10000$

vary $\mu_w = 10, 2$

$\sigma_w = n_w / 5$

II. SIMULATION RESULTS (cont'd)
PERFORMANCE DEGRADATION IS NEGLIGIBLE

and \( m = 10/5, 2 \cdot m = 10/5 \)

for \( \gamma = \frac{5}{10000}, \frac{1}{10000}, \frac{2}{10000} \)

AVGCN + RFI (5 iterations): SIR = -10 dB

II. SIMULATION RESULTS (cont'd)
and \( \mu^m = \mu^m = \mu^m / 5 \)

for \( \gamma = 50 \, 10000, 10 \, 10000 \)

\[ \text{AWGN + RFI (5 iterations): } \text{SIR} = -10 \, \text{dB} \]

II. SIMULATION RESULTS (cont'd)
For $\gamma < 50/10000$ and $10^{-1} > 10$

Performance degradation is negligible for

AWGN + REI (5 iterations): SIR = 0 dB

II. Simulation Results (cont'd)
March 11, 1997

William E. Ryan, Asst. Prof., NMSU
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HIGH RATE TURBO CODES
Rate 3/4 Turbo Codes
8-PFSK T-TCM

(8-BPSK MODULATION T-TCM)

INTRODUCTION TO TURBO-TRELLIS
Estimated time of completion for first round of tests is June 1997

Goal for first round of tests: P6 vs P7/8 curves down to about 1 dB

Software must be modified for block sync and to accept quantized soft decisions

All encoders and decoders will be simulated in software

The turbo code will be the r=1/2 (31,33) code proposed by JPL

Will run the r=1/2, K=7, conv code for a baseline

**Turbo Code Test Through TRRS**
Center for Space Telemetering and Telecommunications
Klopsh School of Electrical and Computer Engineering
New Mexico State University

Assistant Professor

Phillip De Leon

DAMA Career Acquisition
Background of Investigation
Carrier Acquisition

Requirements for DAMA

• Minimal impact to WSC facilities
• Acquisition of service request should have a pace with service request rate
• Should keep pace with service request rate
• DAMA carrier detection and correction
  • DAMA carrier – correct for Doppler shift
  • DAMA carrier – detect DAMA carrier
  • DAMA carrier – detect DAMA carrier

Front-end hardware unit to
Proposed Solution

- Implement solution using digital signal processing (DSP) hardware
- Demodulation
- Pass frequency estimate to receiver for detection
- (DFT) to detect carrier (peak spectral)
- Use windowed, discrete Fourier transform
Assuming prior data acquisition
Approximately ~200µs for estimate

4dB SNR

Reliable frequency estimation down to 23Hz over a 24kHz bandwidth
Reliable frequency estimation to within ±

Motorola DSP56002 processor
Hardware unit built around 40mips

Prototype Unit
DAMA Carrier Acquisition
Proposed Specifications

Main lobe bandwidth of 200KHz in DAMA

null in TDRS spectrum (2287.5MHZ + 6MHZ)

DAMA carrier located in frequency at first
Acquisition Unit
Proposed DAMA Carrier Unit
Main lobe of shifted spectrum preserved in
Signal spectrum
Bandpass filter and frequency-shift DAMA
328KHz-wide band
Shifting DAMA Spectra
- 64K external SRAM
- (100MHz Motorola DSP56301)
- 100mips

Execution rate demands

Point DFT (1MHz A/D)

+3KHz estimation accuracy requires 256

Acquisition Unit (cont)

Proposed DMA Carrier
Driving a VCO

Voltage proportional to estimated frequency for

Fraction of it

Locking tone at estimated frequency (or some

Estimated

Acquisition Unit (cont)

Proposed DAMA Carrier
Service multiple DAMA requests

DAMA carrier

(adaptive) parametric models (AR models) of

"modern spectral estimation"

more efficient frequency estimation, i.e.

characteristics

exploit knowledge of DAMA signal

Further investigations
Conclusions

Prototype and simulation data
Design of DAMA Carrier Acquisition Unit

Time frequency estimates
Prototype hardware provides accurate, real-

Implementation
Problem is well-suited to DSP-based
Non-linear Equalization of Non-linear Satellite Channels

James P. LeBlanc and William E. Ryan

Klipsch School of ECE
New Mexico State University
Use of adaptive non-linear equalization

Reduction of non-linear ISI due to TWL

**Methods**

- Higher symbol rates
- Use of higher order modulation schemes
- Increase data rate through TDRSS

**Goals of Effort**
WSMR incorporates nonlinear equalizer and higher order Loral has installed advanced modem at TDSS ground station at In-house TWT channel implementation Data acquisition (snapshots) of actual TWT channels from Loral

Related Efforts


Related Publications
... allowing Decision Device to estimate transmitted symbol

Equalizer reduces ISI (w/o excessive noise enhancement) ...

Channel introduces noise and intersymbol interference (ISI)

\[ s(k) \]

\[ r(t) \]

\[ y(k) \]

\[ \hat{s}(k-d) \]
Linear feedforward equalizers cannot correct for non-linearities.

Feedforward equalizers suffer noise enhancement.

Decision Directed Feedforward Linear

Linear Feedforward Equalizer (using training)
These will exhibit non-linear noise enhancement.

- Example: Volterra filters

Non-linear equalizers may be implemented for

Adaptive Non-linear Forward Filter
Overall, non-linearity makes analysis difficult.

Linear feedback equalizers can't correct for non-linearities.

DFEs suffer from error propagation.

FSE (forward) DFEs can cancel only post-cursor ISI (use with feedforward).

DFEs do not suffer noise enhancement.
If decision device output is correct

... DFEs can eliminate postcursor without noise enhancement

DFE Attacks Postcursor
Overall non-linearity makes analysis difficult.

RAM-DFE typically converge slowly.

RAM-DFE can be implemented without multipliers.

RAM-DFE can correct for non-linearities.
8-PSK Symbol Errors vs. SNR ($E_s^0/N_0^0$) at Fraction of Symbol Rate (Cutoff of Butterworth Filters is POS)

- FOS = 0.75
- FOS = 0.85

- RAM-DFE
- Linear FSE
may be further improved through use of a "RAM canceler"

improves for higher symbol rates

is modest for low symbol rates

RAM-DFE performance over Linear FSE

Results
Overall performance impact under investigation

Introduces new error mechanism

Non-linear ISI

Use of tentative decisions allows reduction of precursor
Reduces precursor non-linear ISI components

- RAM-canceler with tentative decisions

- Reduces linear precursor ISI.

Linear Fractionally Spaced Equalizer

- Reducing both linear and non-linear postcursor ISI.

- Mitigate noise enhancement,

Use of non-linear DFE (RAM-DFE)

Specifically...

Symbol rates.

Combination of higher order modulation schemes and higher

Increase in data rate through TDRS is achievable using a

Conclusions