



# WBHF Testing over Transatlantic Link

**Presenter:** Mark Jorgenson

## **Contributors**

Netherlands MoD Defence Materiel Organisation:

Jerry Doms & Wim Ketel

Rockwell Collins:

David Church, Brad Butikofer, Randy Nelson

**Rockwell  
Collins**

## Wideband HF (WBHF) Data Waveform Overview

- New MIL-STD-188-110C Appendix D Data Waveform Suite
  - Comprised of eight data waveforms for eight HF bandwidths, 3 kHz through 24 kHz in 3 kHz bandwidth increments
  - All eight waveforms fully autobaud, 12 to 14 data rates, four interleaver options per waveform
- This discussion focuses upon the 12 kHz WBHF waveform tests results between Cedar Rapids, Iowa and Dongen, Netherlands; a 4100 mile (6800 km) multi-hop HF link.
- The table on the next slide describes the 110C Appendix D characteristics for the 12 kHz WBHF waveform. The 12 kHz waveform characteristics used in the transatlantic trials are slightly different, but performance metrics are similar

## 110C Appendix D 12 kHz Waveform Characteristics

Data Rate	Modulation Type	Code Rate	Frame Data Symbols	Frame Known Symbols
300	Walsh	1/2	N/A	N/A
600	BPSK	1/8	192	192
1200	BPSK	1/4	192	192
2400	BPSK	1/3	384	128
4800	BPSK	2/3	384	128
6400	BPSK	3/4	1024	128
12800	QPSK	3/4	1024	128
19200	8PSK	3/4	1024	128
25600	16QAM	3/4	1024	128
32000	32QAM	3/4	1024	128
38400	64QAM	3/4	1024	128
48000	64QAM	8/9	1080	72
64000	256QAM	8/9	1080	72

## Transatlantic WBHF Link Participants and Goals

- WBHF transatlantic over-the-air test research teams
  - Receive station at Dongen, Netherlands sponsored by the Dutch MoD Defence Materiel Organisation:
    - Wim Ketel and Jerry Doms
    - “LCW” on the next slide denotes “Logistic Centre Woensdrecht “
    - Woensdrecht is the town where Jerry Doms’ headquarters is located.
  - Rockwell Collins transmit station in Cedar Rapids, Iowa (USA):
    - Mark Jorgenson, David Church, Brad Butikofer, and Randy Nelson
- Mission is to study the feasibility of multi-hop data transport over HF channels wider than 3 kHz
  - Characterize the propagation effects over multiple time zones (seven hour time-of-day delta)
    - Ionospheric effects of day and night disparities at TX and RX sites
  - Signal reflection effects of ground and sea surfaces over a 12 kHz HF channel and its impact on high density waveform constellations

# Research LCW C4i & OEM

NATO HF Wide Band High Speed Data research program



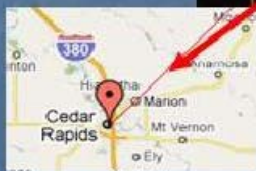
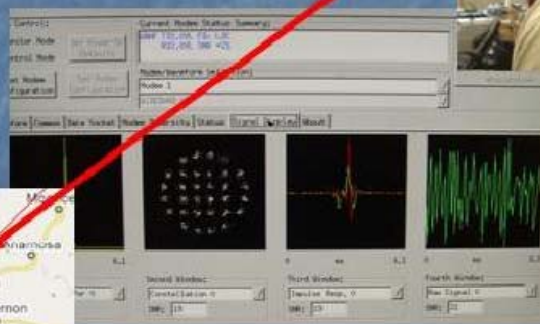
LCW C4i radio Lab.



Jerry Doms  
LCW C4i BLOS Expert



Constellation diagrams



## WBHF System Specifics for Transatlantic Link

- Netherlands Receive Site Equipment
  - Receive antenna in the Netherlands primarily a Windom dipole antenna, with two trials using a remote log periodic antenna
  - HF receiver supporting 12 kHz HF channels
  - WBHF modem with prototype 12 kHz waveform
  - Fireberd 8000 as the synchronous data sink
- Iowa (USA) Transmit Site Equipment
  - Log periodic antenna directed at Netherlands
    - Take-off angle 20° to 25° dependent upon frequency
  - Average PA output power: 1 KW
  - HF transmitter supporting 12 kHz HF channels
  - WBHF modem with prototype 12 kHz waveform; all trials using 7.68 second interleaver
  - Fireberd 6000A as the synchronous data source

## WBHF Transatlantic Data Transport Trials

- Majority of tests in November and December 2010 (minimum daylight time period)
- Utilized varying times of day for over-the-air trials, examples:
  - Midnight Iowa time, 7 AM Netherlands time (not successful)
  - Starting at 7 AM Iowa time (dawn), 2 PM Netherlands time, were majority of test times and resulted in the best results
- WBHF “Dial” Frequencies
  - Night-to-Daylight: 6 MHz to 9 MHz range (night transmit to daylight receive link was unsuccessful on the one attempt)
  - Daylight-to-Daylight: 11 MHz to 17 MHz range
  - Best results were 1 to 2 hours after dawn on the transmit end (USA)

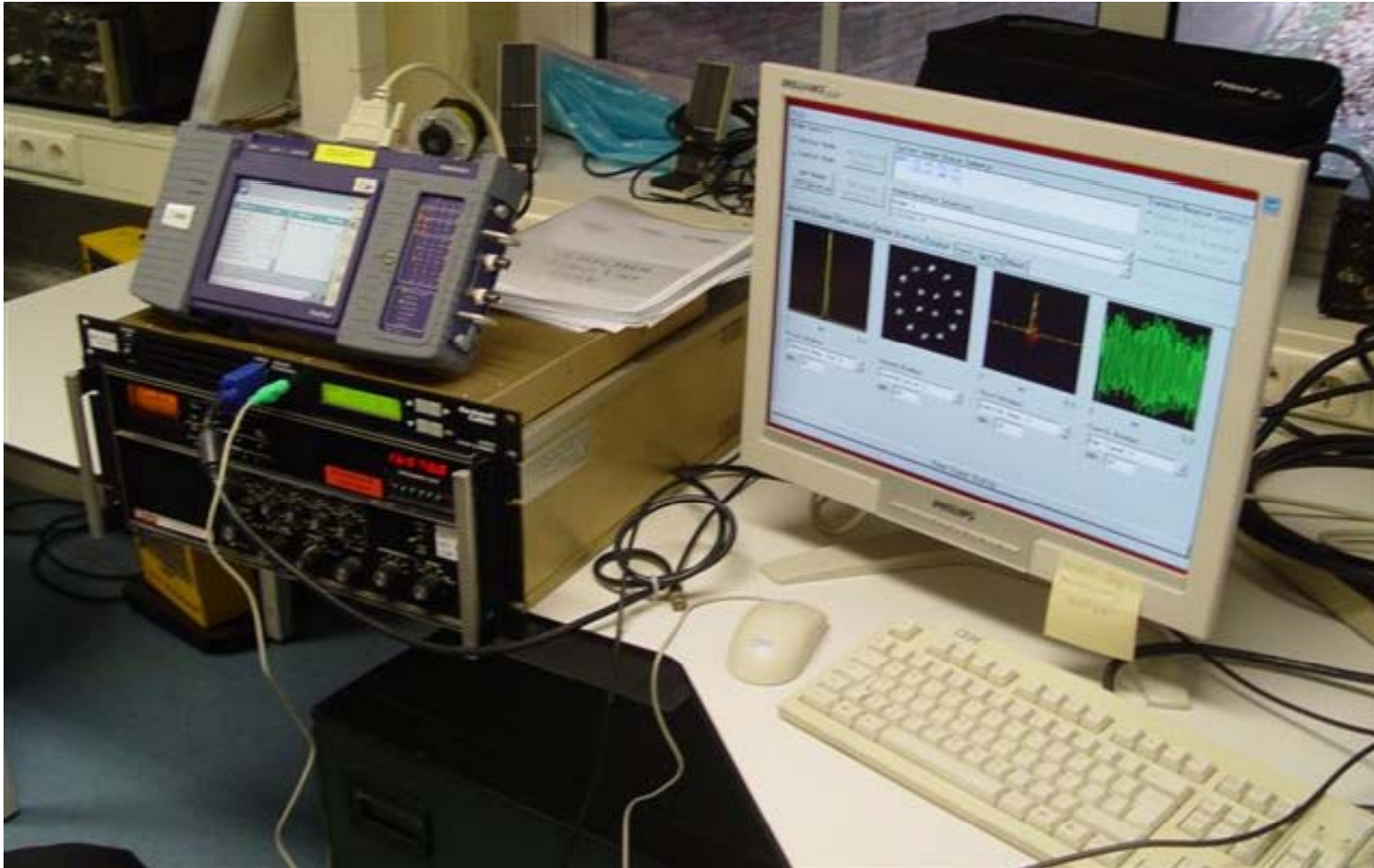
## **WBHF Iowa-Netherlands Testing 11-17-2010**

- Transmit site (Iowa, USA) and receive site (Netherlands) HF antenna and equipment the same as described earlier
  - Setup trials conducted on Tuesday, November 16, 2010, for establishing channel characteristics and ensuring systems and test equipment were functioning properly
  - Receive antenna (Netherlands site) switched to single element dipole prior to the Wednesday, November 17<sup>th</sup> over-the-air trials
- Following slides are photos taken at the Netherlands receive site includes test bed, lead test engineer Jerry Doms, and modem signal display graphical suite

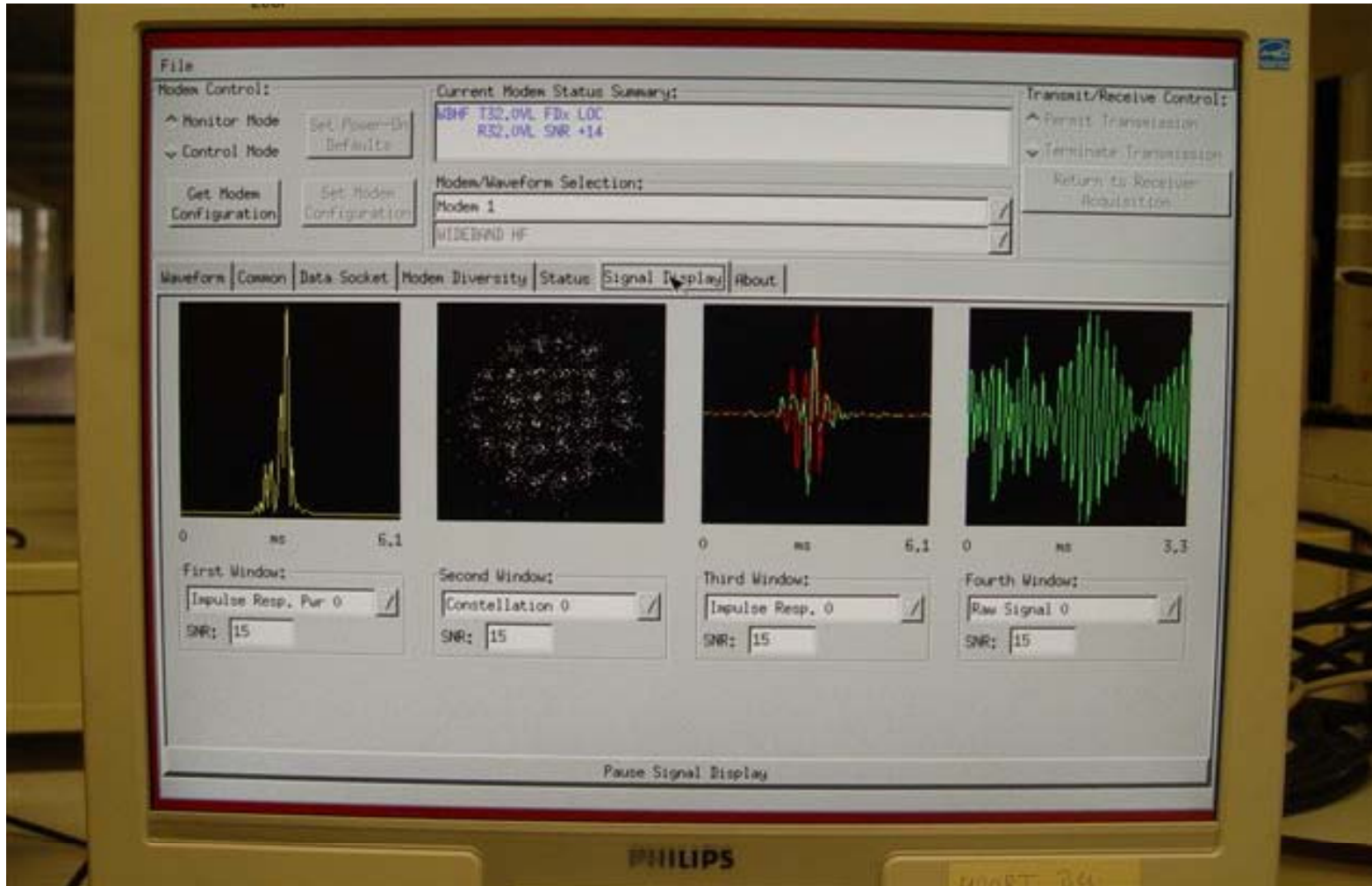
## Jerry Doms Preparing Receive Station for Trials



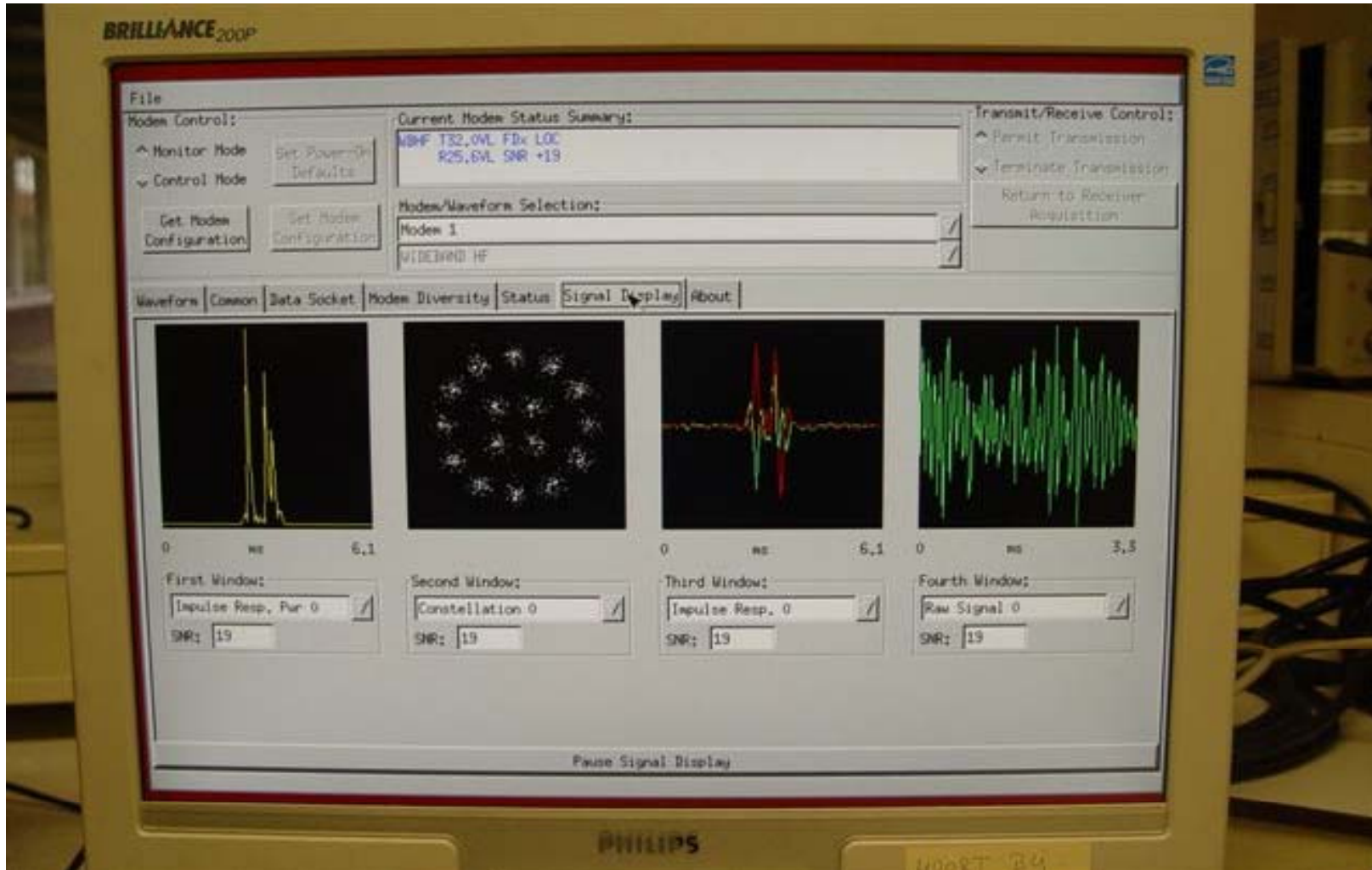
## Netherlands Station Receiving 25.6 kbps Data



## Netherlands Receiving 32.0 kbps Data (note multi-path)



## Netherlands Receiving 25.6 kbps WBHF Data



## Time Sampled BER and BLER Reception Results

- **Following slide provides BER, Block Error Rate (BLER), RF dial frequency, and other data recorded during Iowa-Netherlands WBHF trials on November 17, 2010**
- **The “Sample Time (CST)” column includes the time that data points were recorded during various transmissions**
  - **“CST” is Central Standard Time, the time of day in Iowa, USA**
- **Consecutive rows populated with data denote a single reception with periodic recorded data samples**
  - **Blank rows delineate distinct transmission-reception trials**

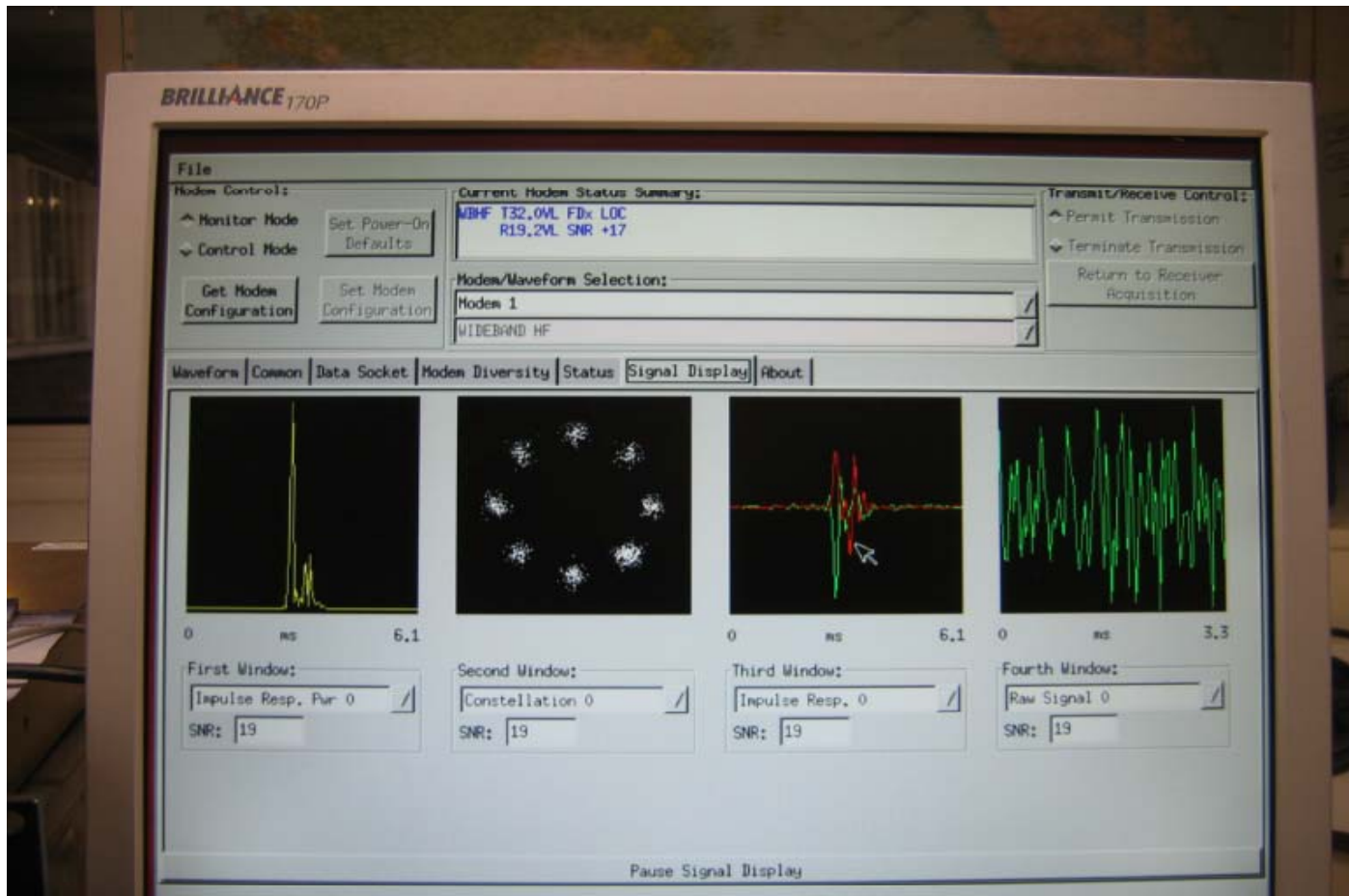
## 11-17-2010 Iowa-Netherlands WBHF Testing Results

RF Freq (MHz)	Data Rate (kbps)	Sample Time (CST)	Blocks of Data	Bit Errors	BER	Block Errors	BLER
<b>16.07</b>	19.2	0719	5,580	0	0	0	0
<b>16.07</b>	25.6	0721	1,334	0	0	0	0
	25.6	0722	3,277	0	0	0	0
	25.6	0724	6,282	0	0	0	0
<b>17.48</b>	32.0	0820	3,000	2033	6.7 E-4	NA	NA
	32.0	0822	6,000	2095	3.4 E-4	NA	NA
	32.0	0825	11,000	2095	1.9 E-4	NA	NA
<b>16.07</b>	38.4	0748	5,000	69,000	1.38 E-2	NA	NA

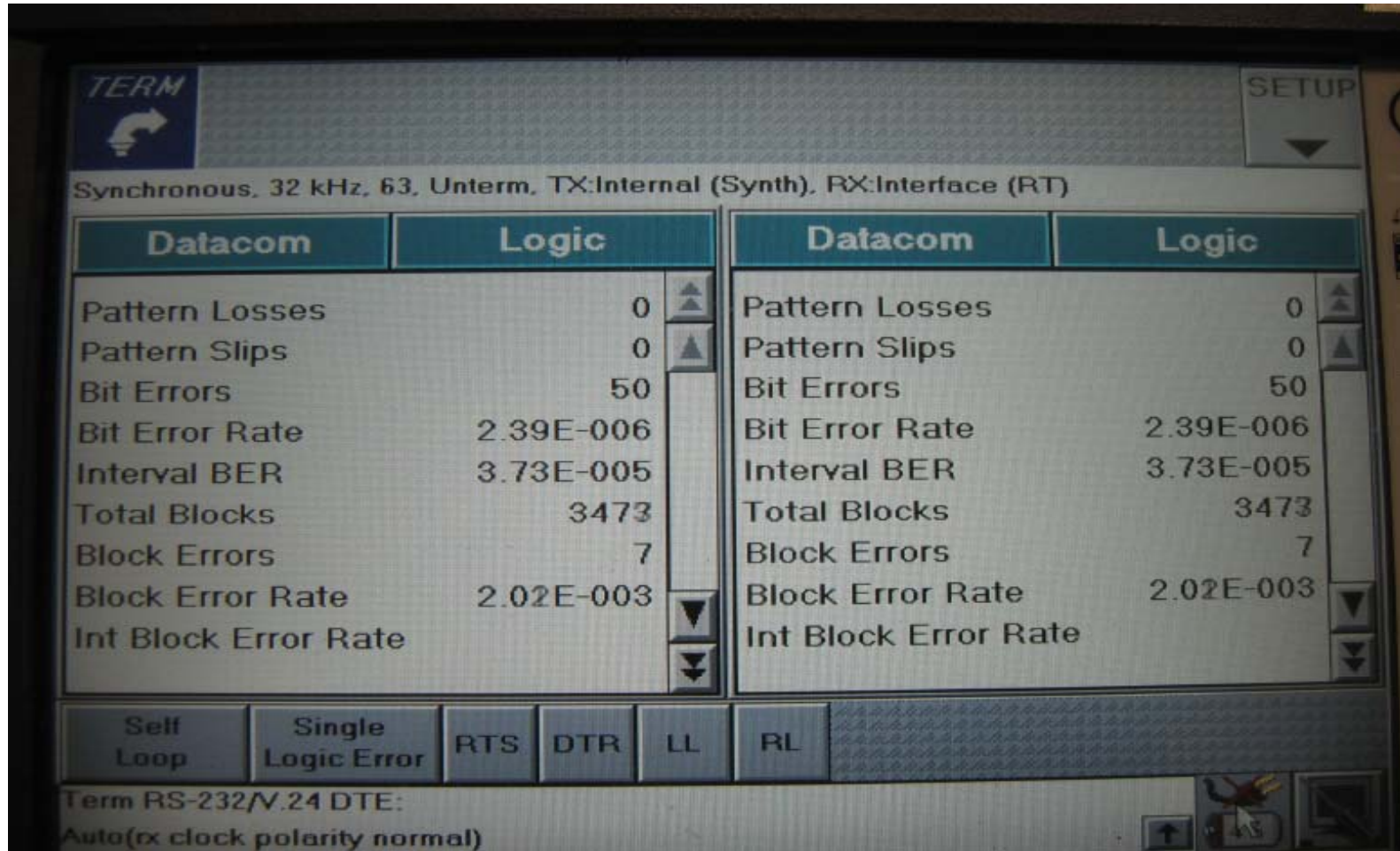
## **WBHF Transatlantic Data Transport Trials, 12-16-2010**

- The next four slides are photos of the receive station's WBHF test equipment in Dongen, Netherlands:
  - WBHF modem's four signal display graphics windows, described from left to right:
    - Impulse response power
    - Signal constellation, an 8PSK constellation (19.2 kbps) and 16QAM constellation (25.6 kbps)
    - Impulse response I-Q components
    - Raw audio signal from radio receiver
  - Photos of the receive station's Bit Error Rate Test (BERT) equipment illustrating a snapshot of the error statistics

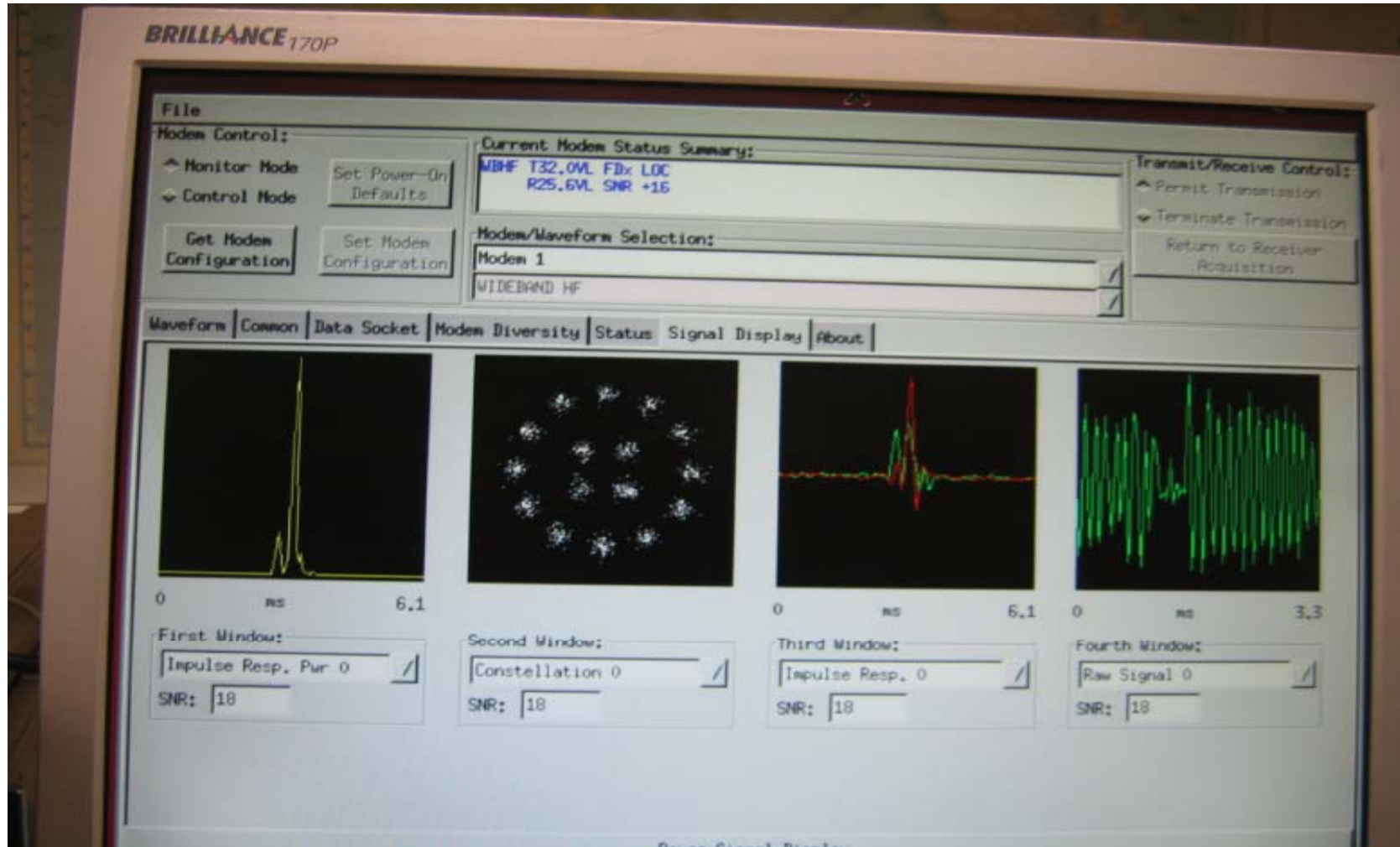
## 19.2 kbps Reception: 15.94 MHz, 0745 CST, 12-16-2010



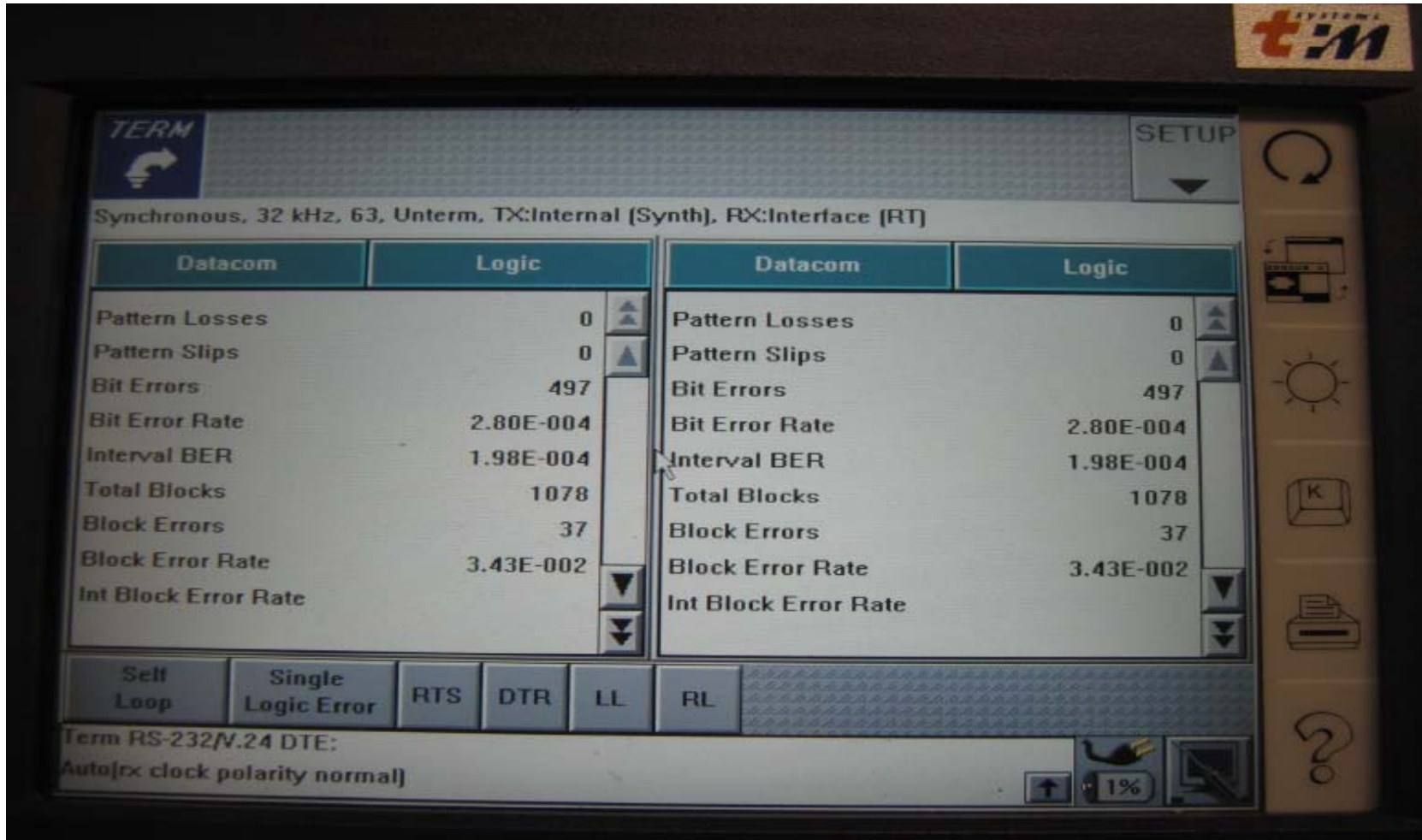
## 19.2 kbps BER: 15.94 MHz, 0748 CST, 12-16-2010



## 25.6 kbps Reception: 16.09 MHz, 0813 CST, 12-16-2010



25.6 kbps BER: 16.09 MHz, SNR 14-16 dB, 12-16-2010



## **BER and BLER Reception Results**

- **Following slide provides BER, Block Error Rate (BLER), RF dial frequency, and other data recorded during Iowa-Netherlands WBHF trials on December 16, 2010**
- **The “Sample Time (CST)” column includes the time that data points were recorded during various transmissions**
  - **“CST” is Central Standard Time, the time of day in Iowa, USA**
- **Consecutive rows populated with data denote a single reception with periodic recorded data samples**
  - **Blank rows delineate distinct transmission-reception trials**

## Snapshots of 12-16-2010 Iowa-Netherlands Testing

RF Freq (MHz)	Data Rate (kbps)	Sample Time (CST)	Blocks of Data	Bit Errors	BER	Block Errors	BLER
<b>15.94</b>	19.2	0747	2886	44	2.17 E-6	6	2.08 E-3
	19.2	0748	3473	50	2.39 E-6	7	2.02 E-3
<b>16.09</b>	19.2	0807	1026	8,414	2.26 E-3	267	2.60 E-1
	19.2	0810	5359	17,538	2.17 E-3	399	7.45 E-2
	19.2	0811	5470	17,673	2.16 E-3	406	7.42 E-2
<b>16.09</b>	19.2	0823	1369	0	0	0	0
<b>16.09</b>	25.6	0828	1689	6,084	2.99 E-3	144	8.53 E-2
	25.6	0831	5772	26,803	4.23 E-3	578	1.00 E-1
	25.6	0831	6028	26,135	4.07 E-3	581	9.64 E-2

## Other WBHF Netherlands-Iowa Link Comments

- Signal-to-Noise-Ratio (SNR) Ranges
  - Periodic deep signal fades with SNR varying from +11 dB to +23 dB within two minute time frames
  - Highest SNR recorded at a given time +26 dB
  - Lowest SNR recorded -2 dB using STANAG 4415 (3 kHz channel)
- Other observations:
  - Channel interferers periodic, but not excessive
  - Multi-path delay spreads estimates never over 1 msec
  - Optimal links achieved during daylight at both stations, particularly one to two hours after sunrise at the Iowa station
  - Trials with 6 kHz and 3 kHz HF channels also conducted

## More WBHF Netherlands-Iowa Link Comments

- 6 kHz WBHF channel trials (one trial on 11-17-2010)
  - 24 kbps data rate (64QAM, rate 8/9 coding) successful for awhile before losing synchronization
  - 19.2 kbps data rate (64QAM, rate 3/4 coding) maintained synchronization much better with BER 2.6 E-2 to 1.2 E-3 range
  - Successful 64QAM trials exhibited SNR range of 16 dB to 20 dB
- 3 kHz channel trials (one trial on 11-17-2010)
  - 75 bps, 600 bps, and 2400 bps data rates performed very well with few or no bit errors

## What's Next for Transatlantic WBHF Trials?

- Characterize additional bandwidths, 9 kHz, 15 kHz and wider if possible to determine performance and probability of wider band HF channel availability
- Transatlantic transport of images and video over WBHF channels
- Experiment with shorter interleaver depths for short data bursts
- Vary PA average output power levels to determine the minimum power levels required for reliable multi-hop WBHF data transport

## Special Thanks.....

- The transatlantic WBHF trials team extend special recognition to Jerry Doms (Netherlands Government) along with David Church and Brad Butikofer (Rockwell Collins)
- These gentlemen got up late at night and early many mornings to support the trials, and acquired invaluable data for characterizing WBHF performance over a transatlantic link
- Wim Ketel for organizing the Netherlands side of the WBHF transatlantic link

**Questions, Comments, Suggestions?**

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