VHF Communications via Equatorial Electrojet Scattering: Revisited

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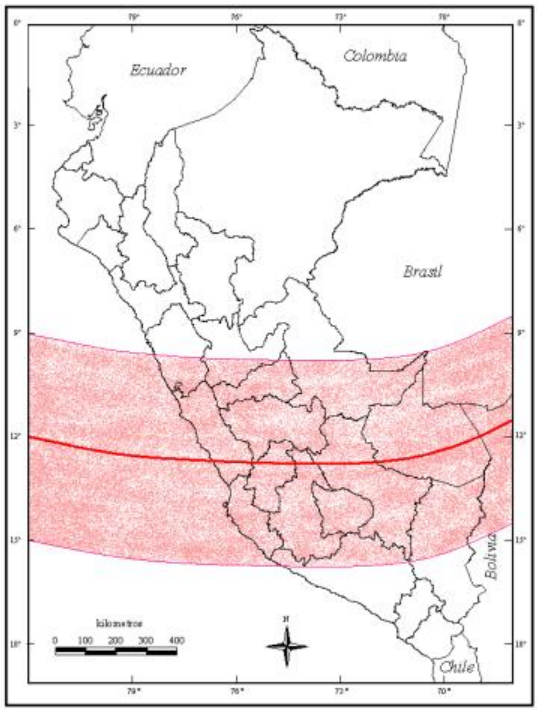
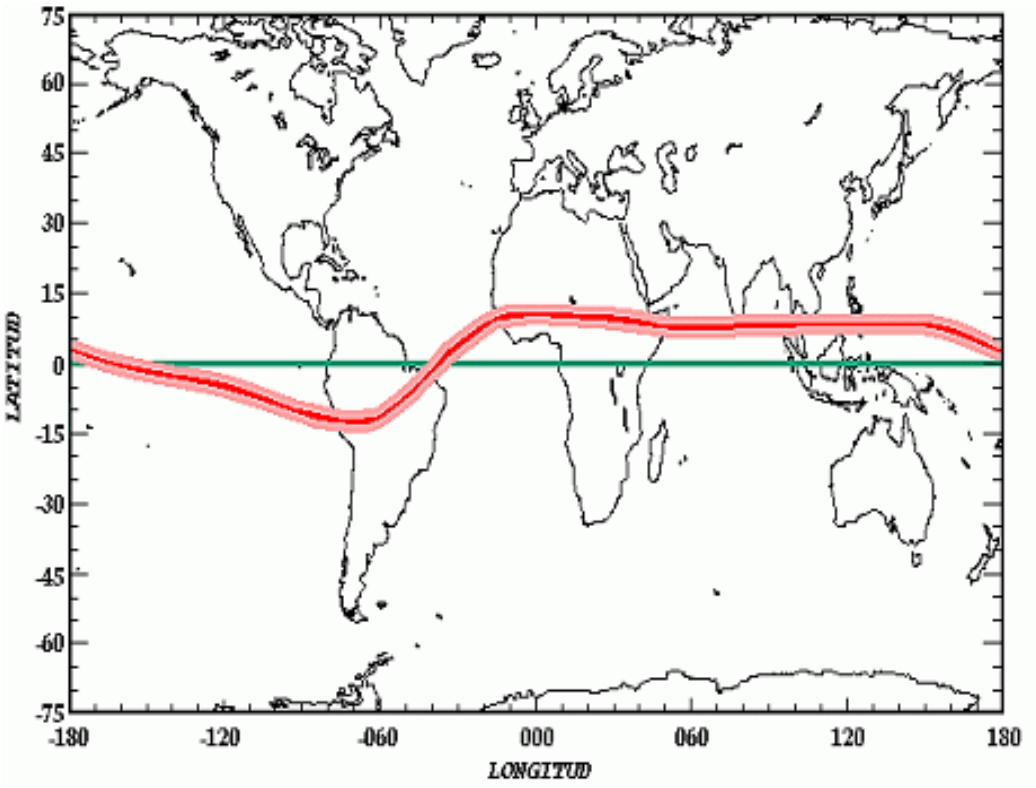
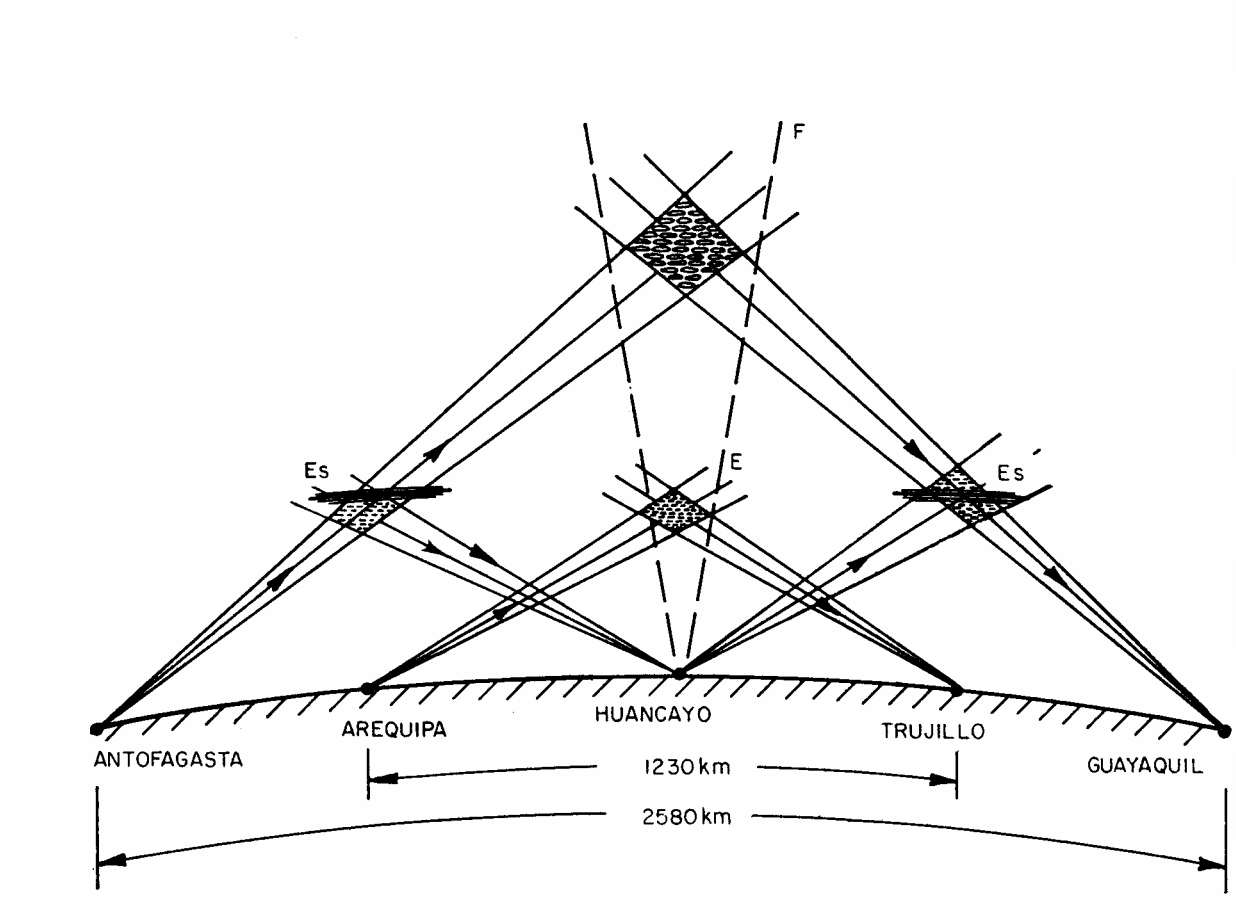
EEJ

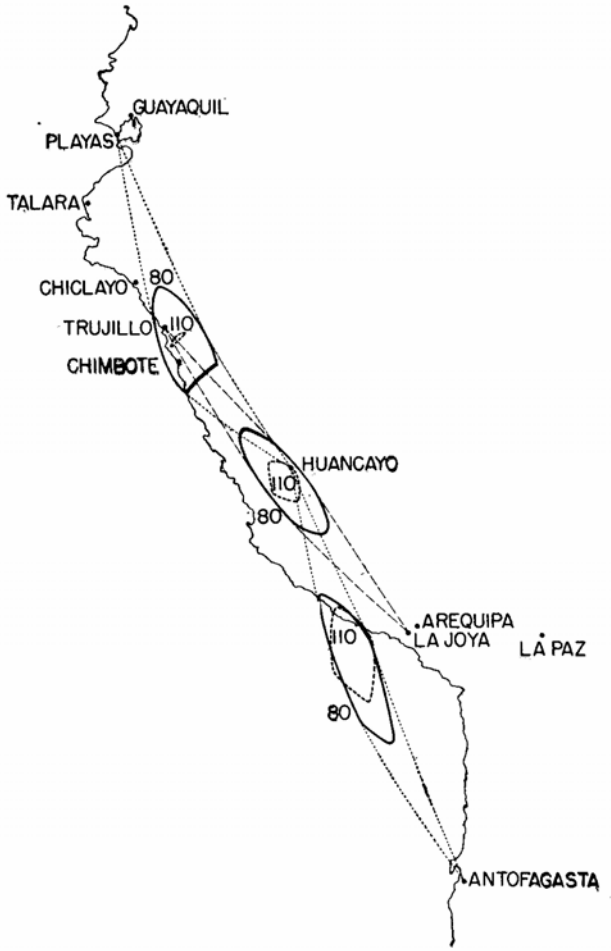

Ecuador
Colombia
Brasil
Bolivia
Chile
kilometros
0 100 200 300 400


75
60
45
30
15
0
-15
-30
-45
-60
-75
LATITUD
-180
-120
-060
000
060
120
180
LONGITUD

IGY Experiment: Configuration

(adapted from *Cohen and Bowles* [1963])





Magnetic Equator

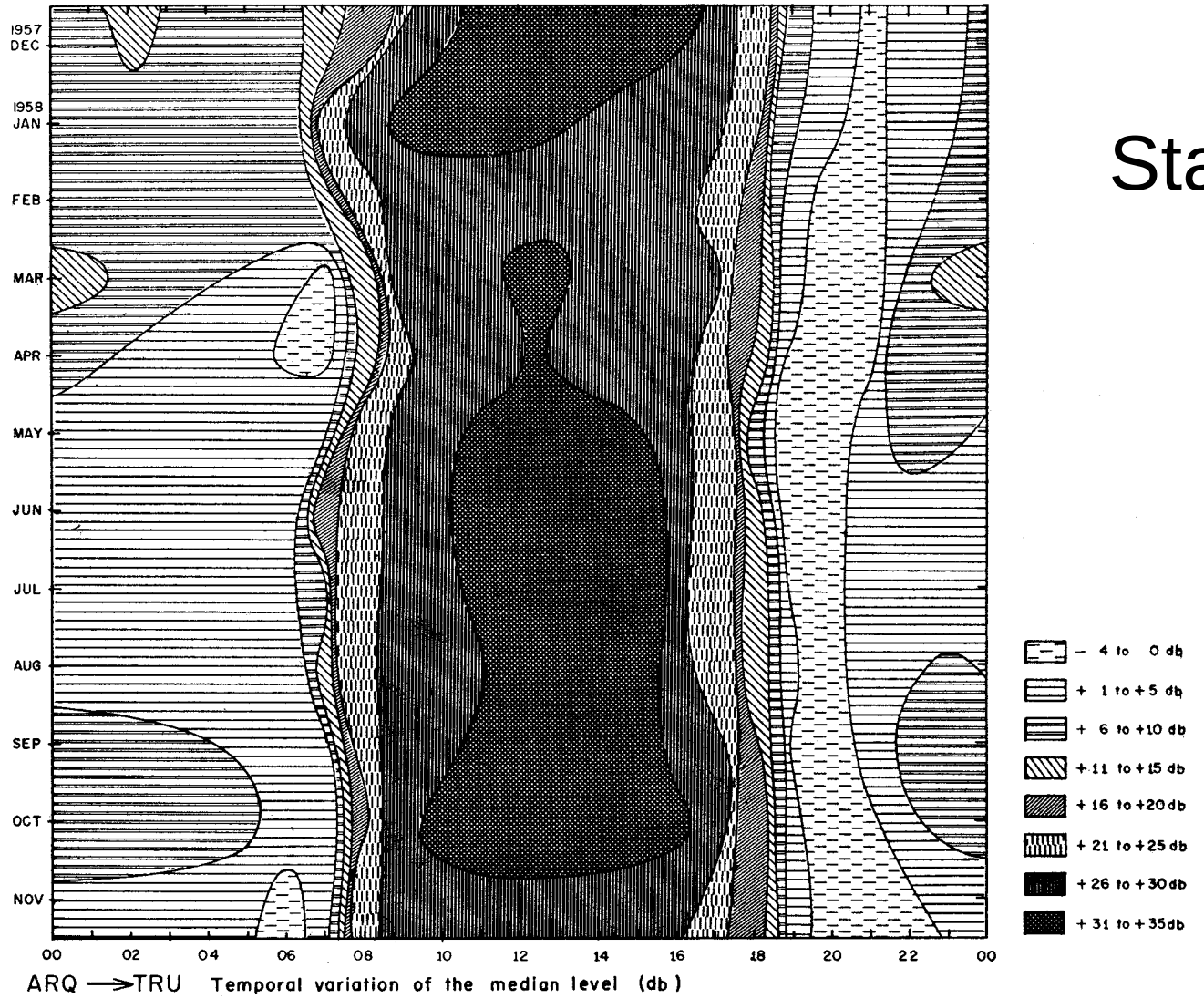
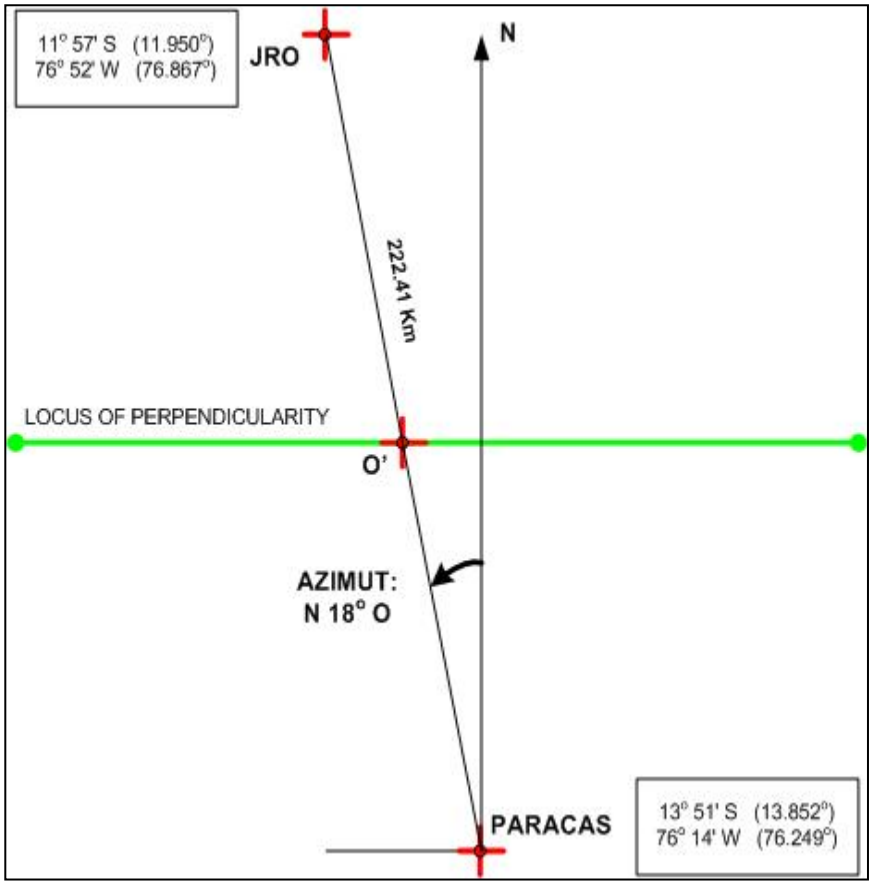
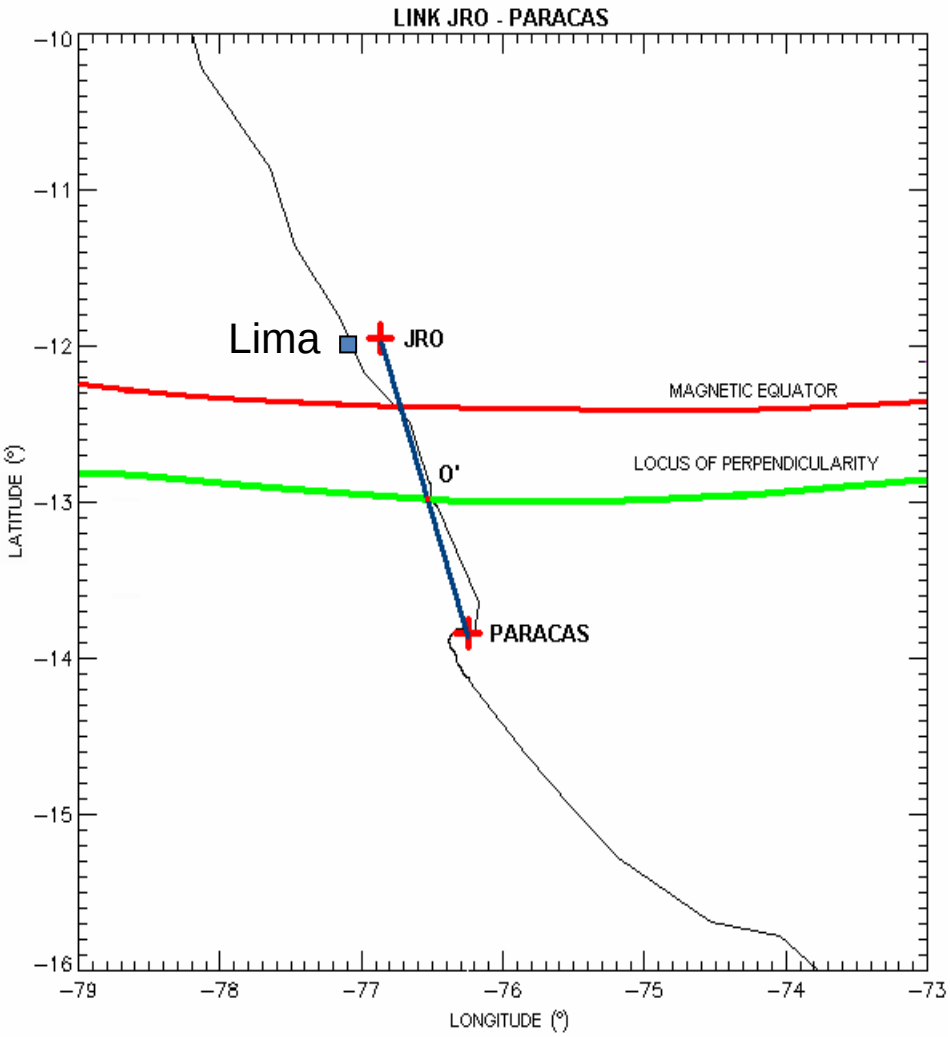


FIGURE 17. *Contours showing the temporal and seasonal variation of the range of signal strength exceeded 50 percent of the time over the central path.*

IGY Statistics

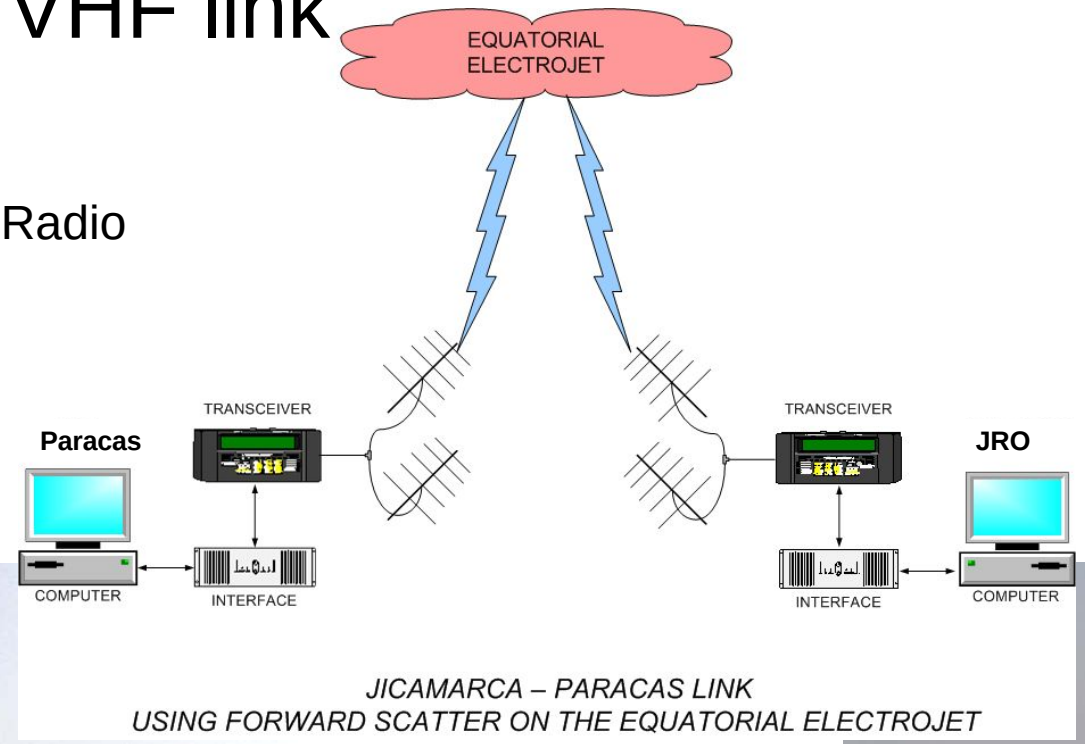
Jicamarca – Paracas
Point-to-Point VHF link



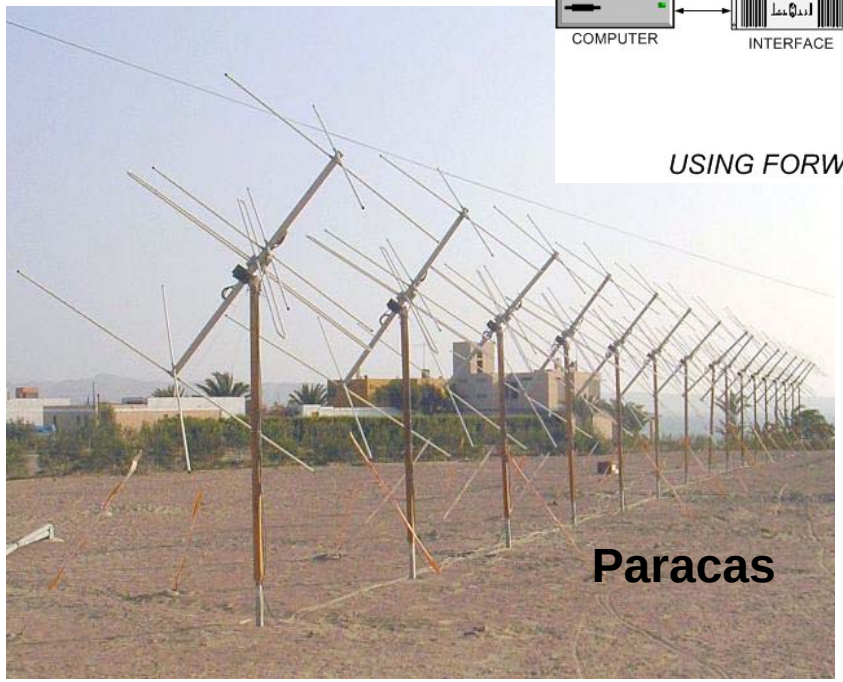


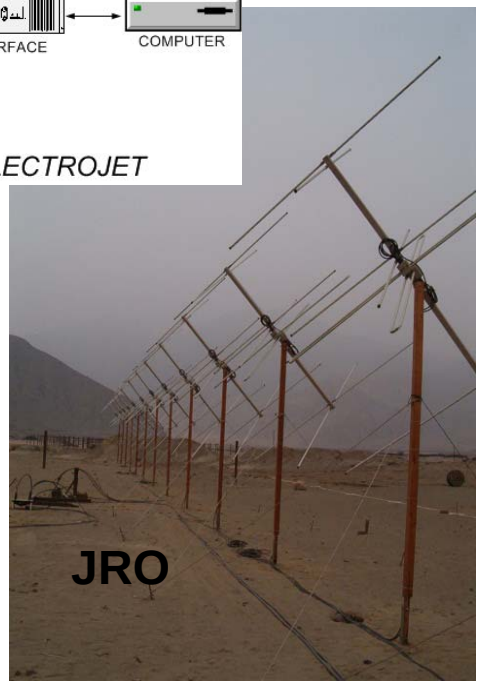
Jicamarca – Paracas
Point-to-Point VHF link

Two TX-RX stations:
Personal Computer
100W Multiband Amateur Radio
16 Yagi antennas
PC-to-Radio Interface
GPS (synchronization)



JICAMARCA – PARACAS LINK
USING FORWARD SCATTER ON THE EQUATORIAL ELECTROJET



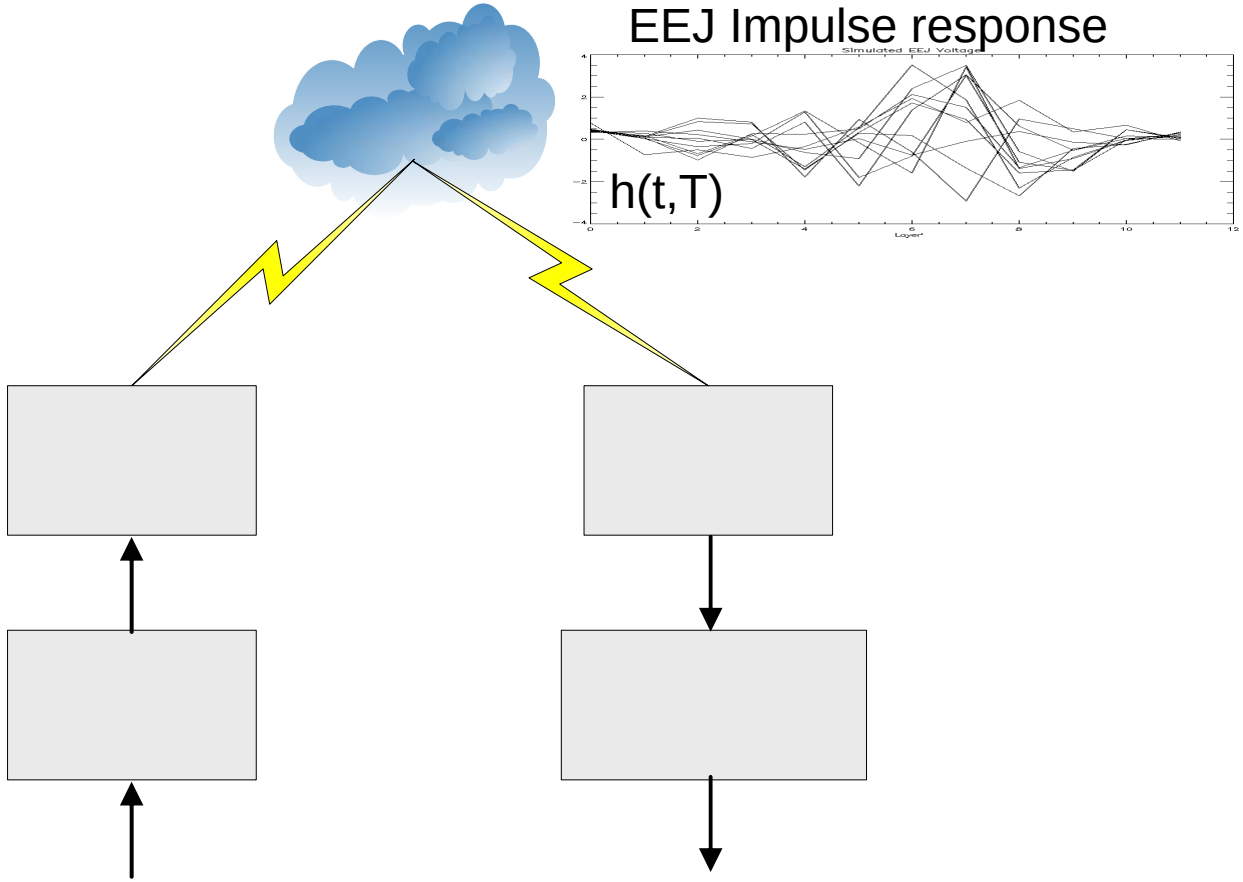


EEJ Communications: Voice examples

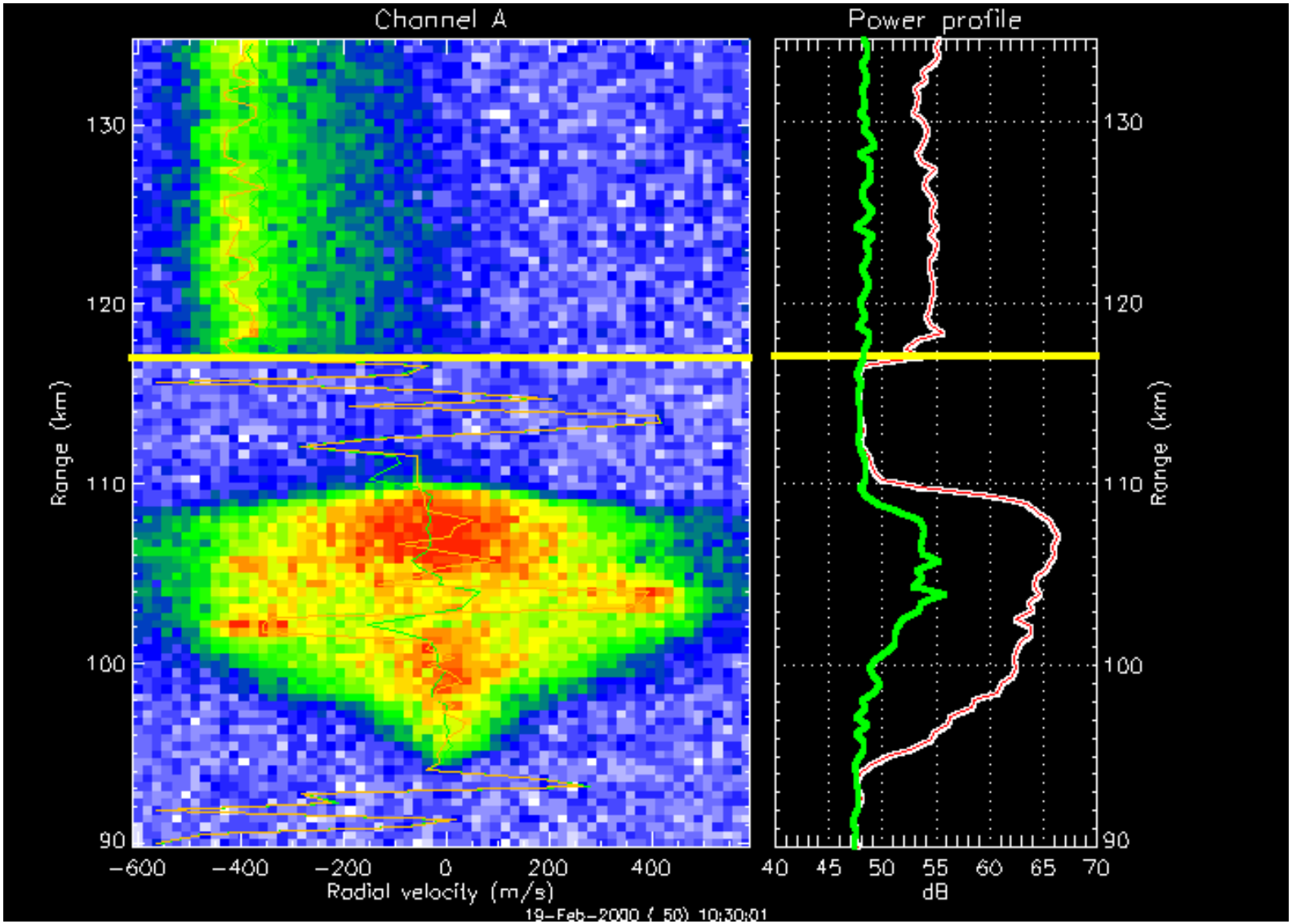
- FM Demo
  - Good SNR
  - Changing gains (100 W , 30 W)
- LSB Demo

EEJ Simulator: Block Diagram

Voice

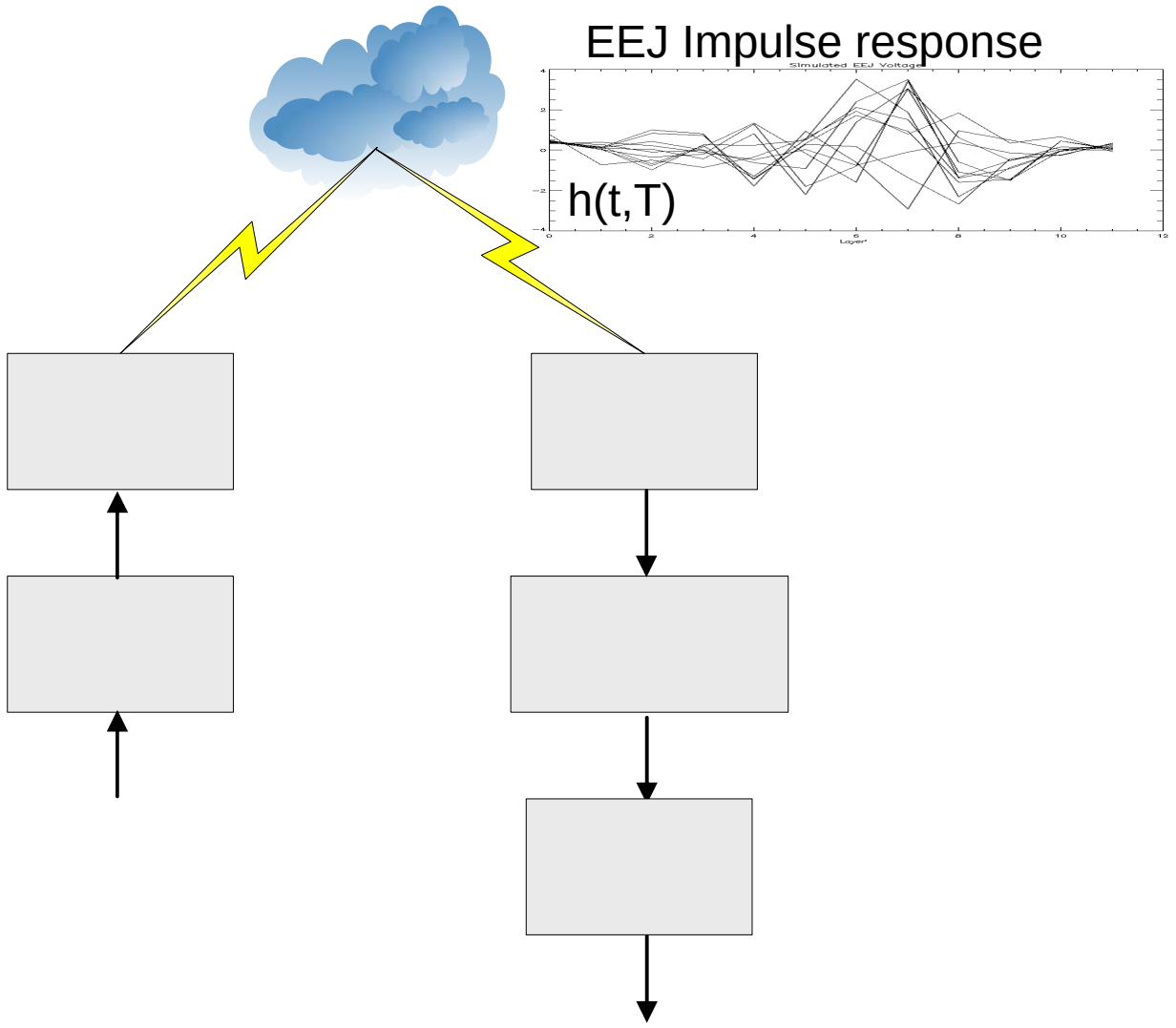


EEJ Backscatter example

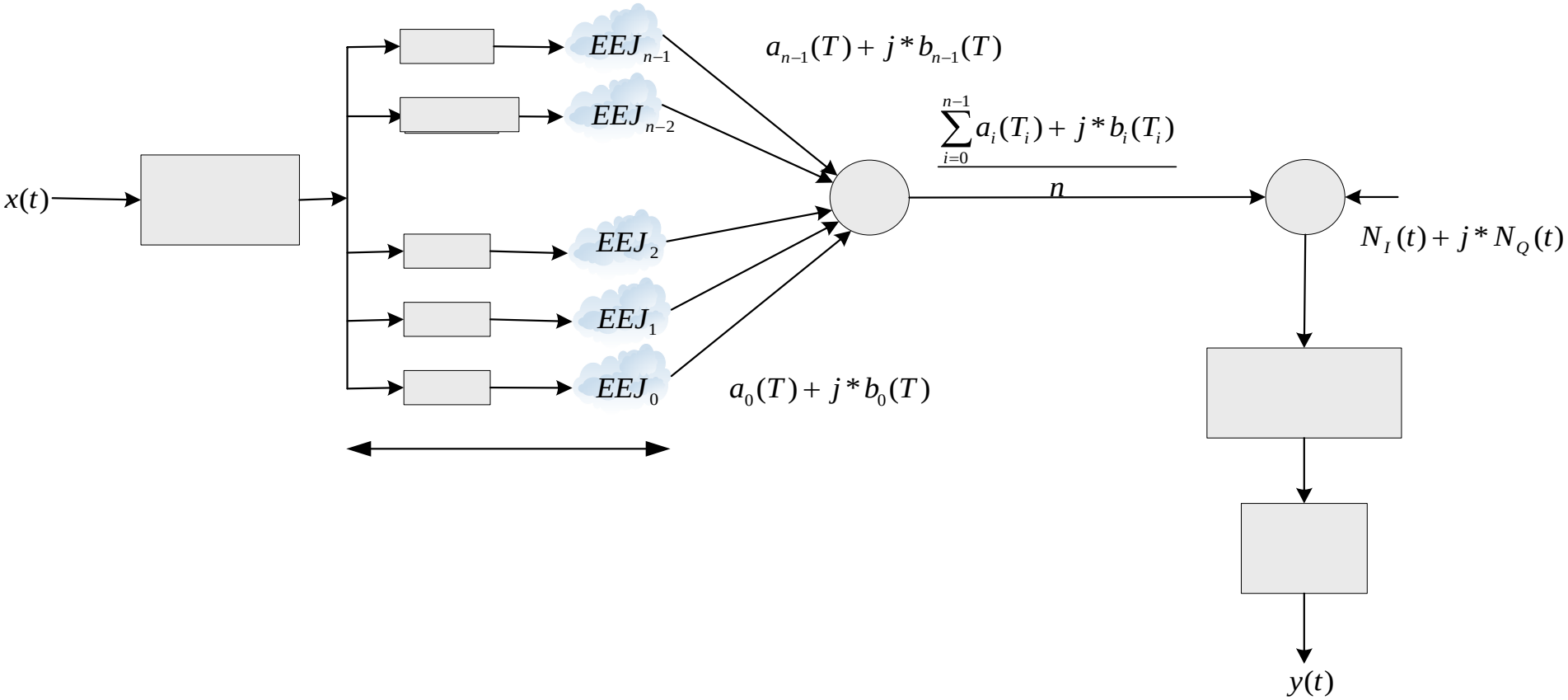


EEJ Simulator: Block Diagram

Data



EEJ Simulator: Many layers



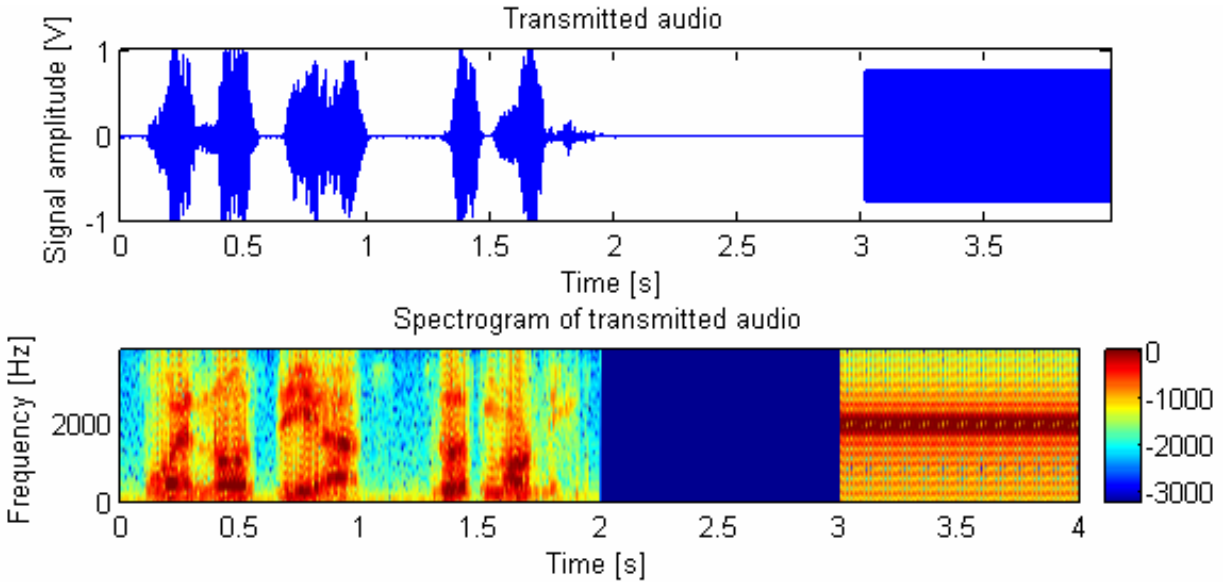
$\delta(t-n\tau)$

Results: Voice

Paramater to quantify quality of “voice” communications:

Correlation coefficient between received and transmitted audio.

Transmitted Audio

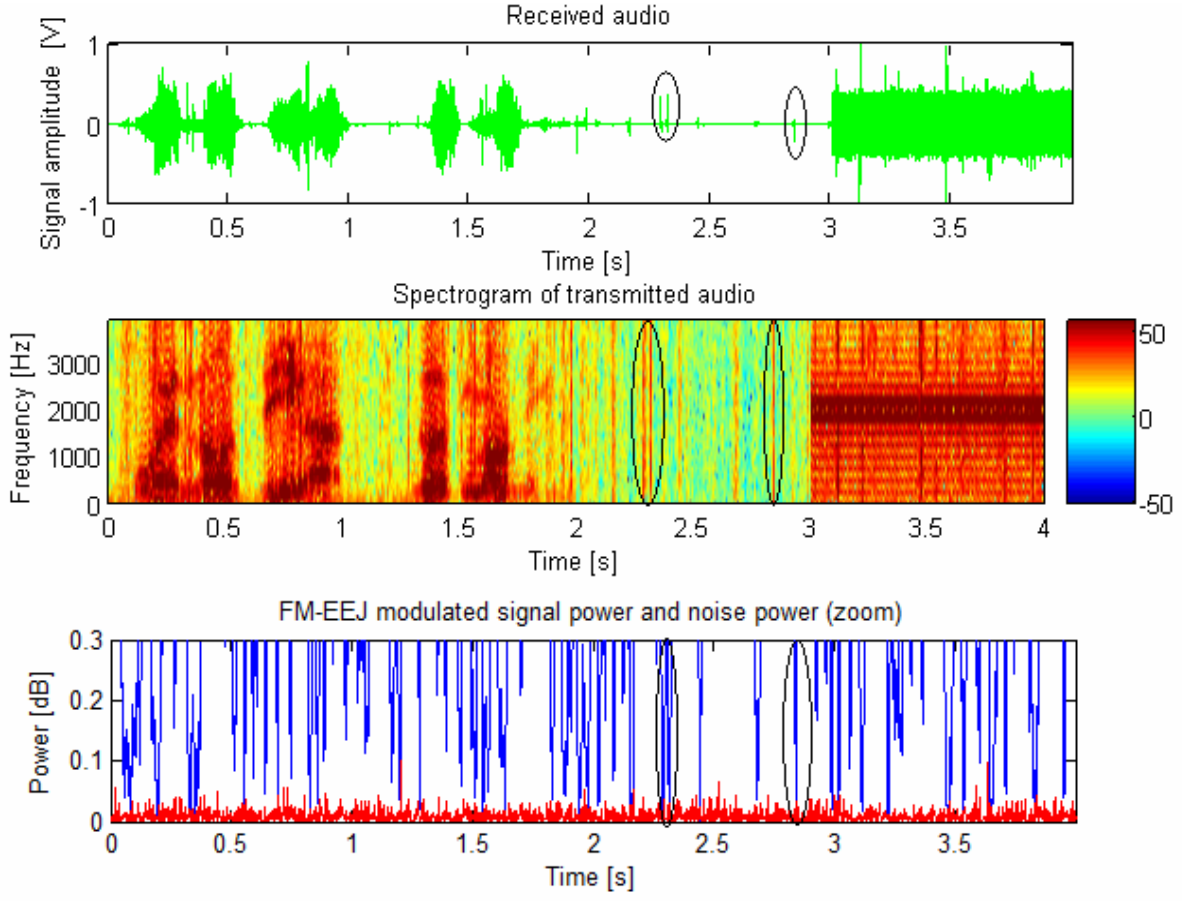


Transmitted audio and its spectrogram

Results: Voice

Crack characterizacion

- High SNR



SNR 20 dB

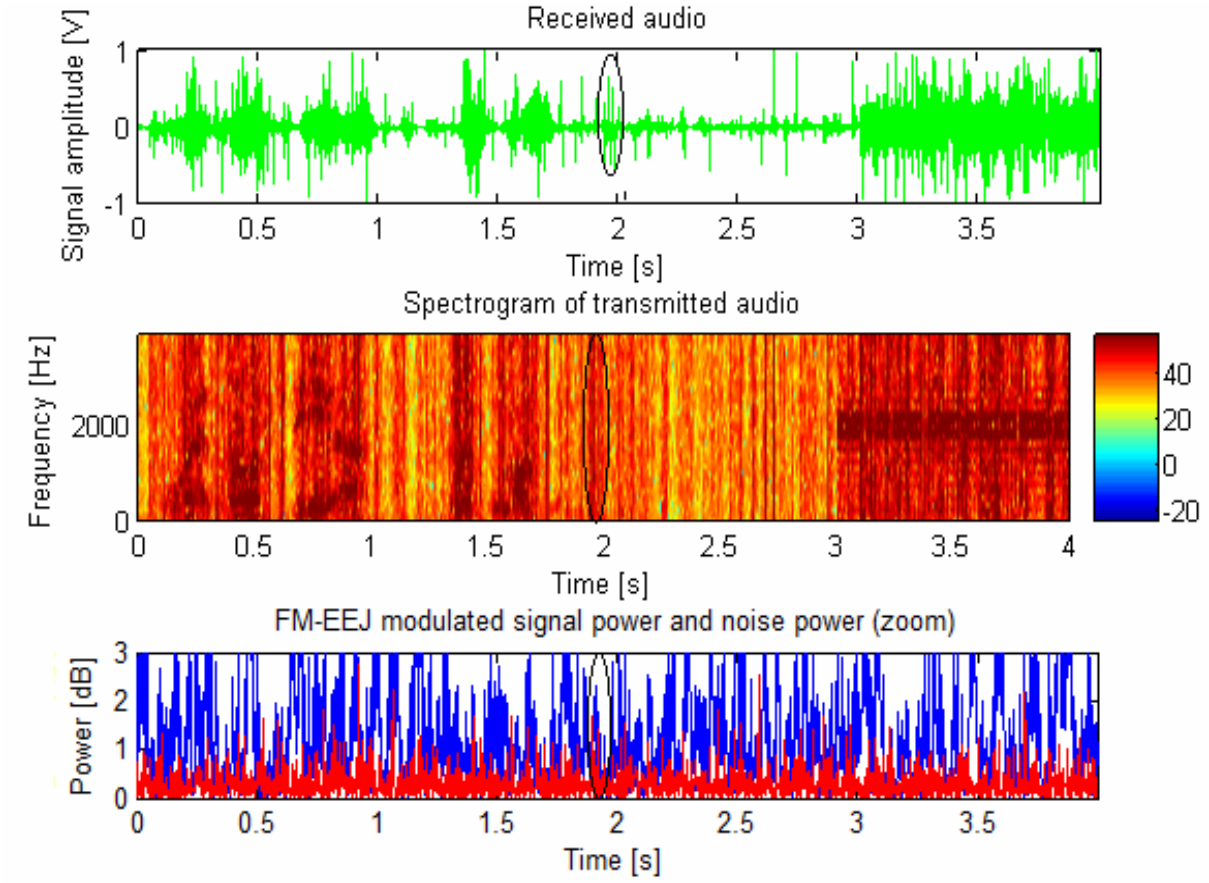
Spectral width = 10 H

EEJ width -> 0 (1 laye

Results: Voice

Crack characterizacion

- Low SNR



SNR 5 dB

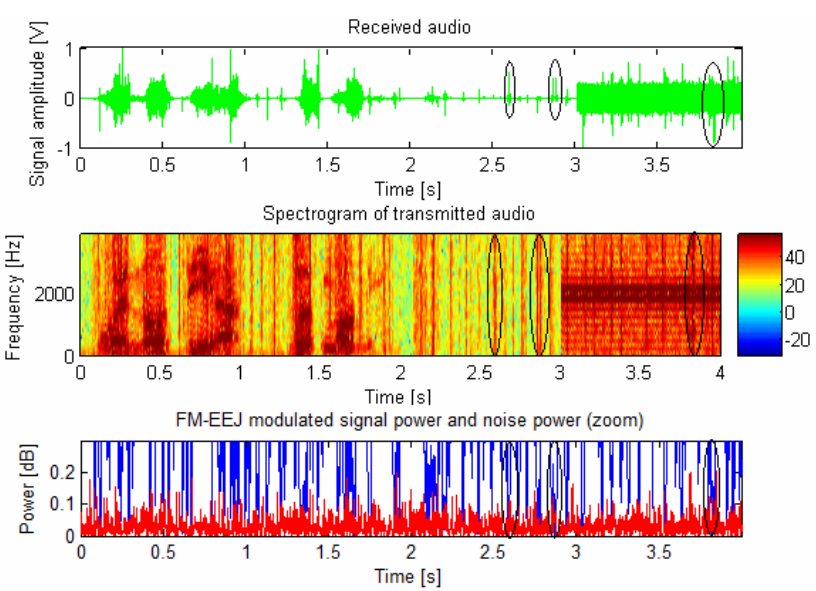
Spectral width = 10 H

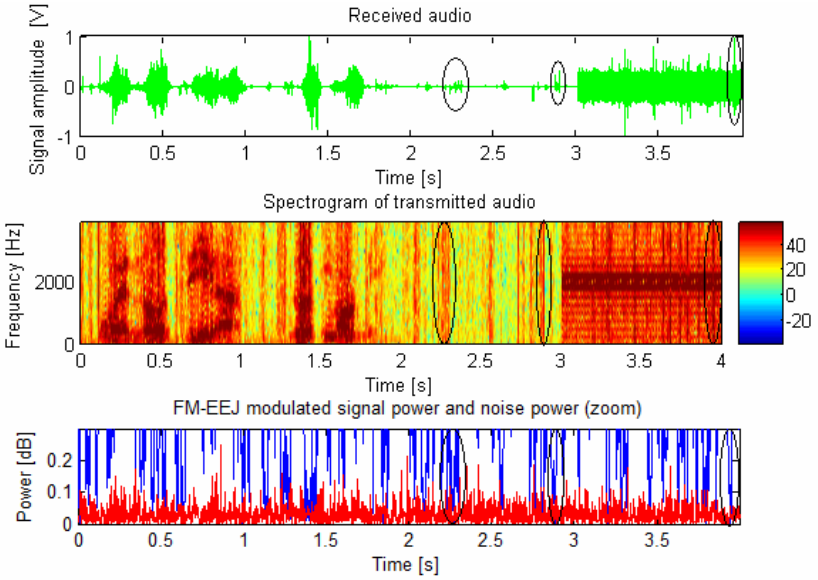
EEJ width -> 0 (1 laye

Results: Voice

Crack characterization

- Two independent realizations



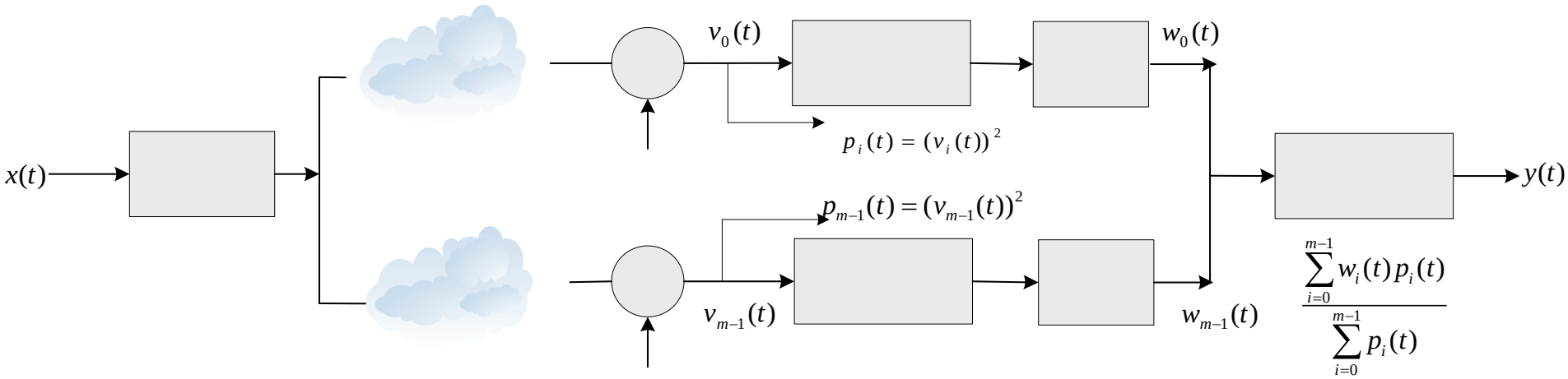


SNR 15 dB

Spectral width = 10 Hz

EEJ width -> 0 (1 layer)

EEJ Simulator: Diversity



Voice Simulations: SNR

Spectral width = 10 Hz

SNR 30 dB

SNR 20 dB

SNR 10 dB

SNR 0 dB

No fading

SNR 30 dB

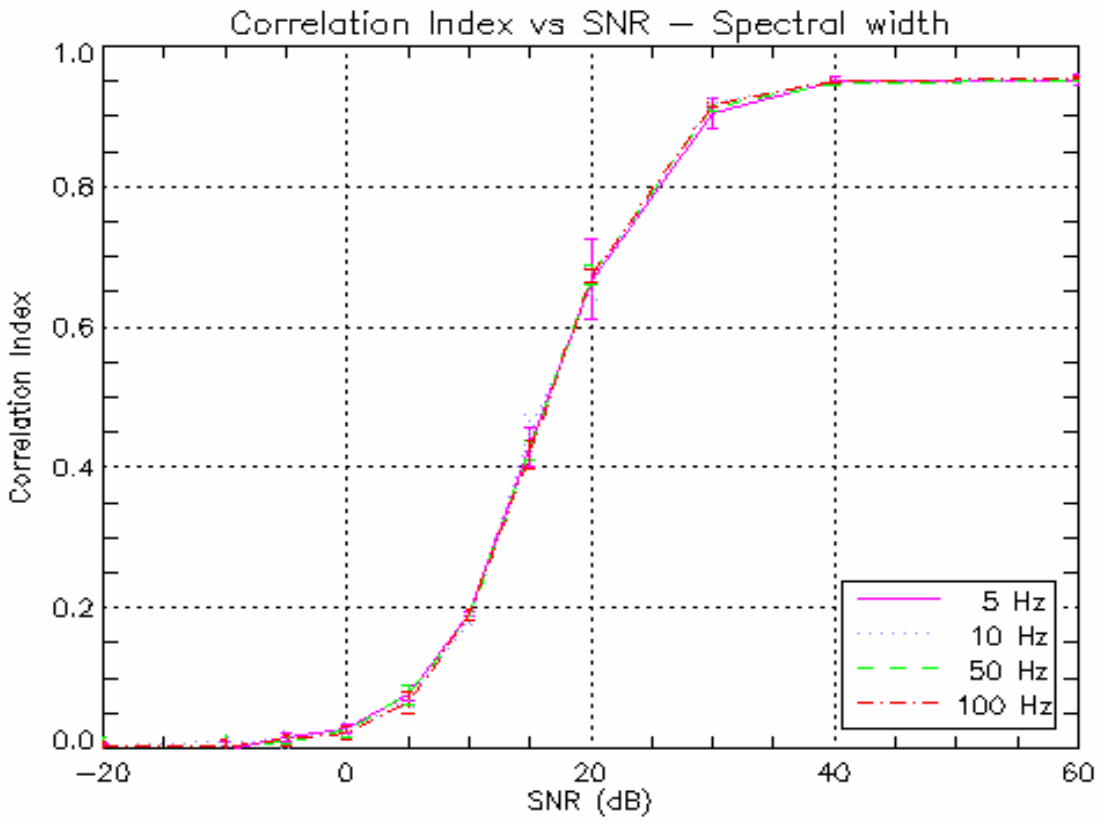
SNR 20 dB

SNR 10 dB

SNR 0 dB

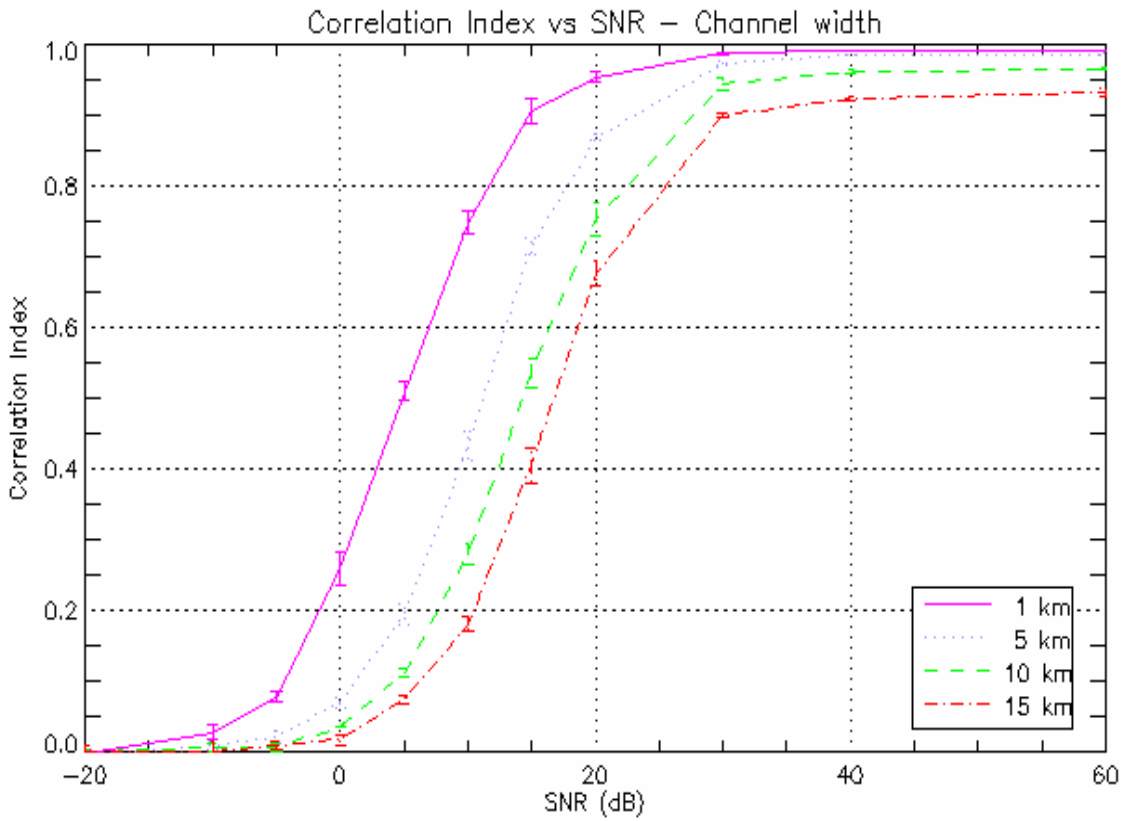
Parameters	Without diversity	With Diversity
FM, SNR = 20 dB, SW = 20 Hz		
FM, SNR = 20 dB, SW = 50 Hz		
FM, SNR = 10 dB, SW = 20 Hz		

Voice Results:
SNR and EEJ Spectral width



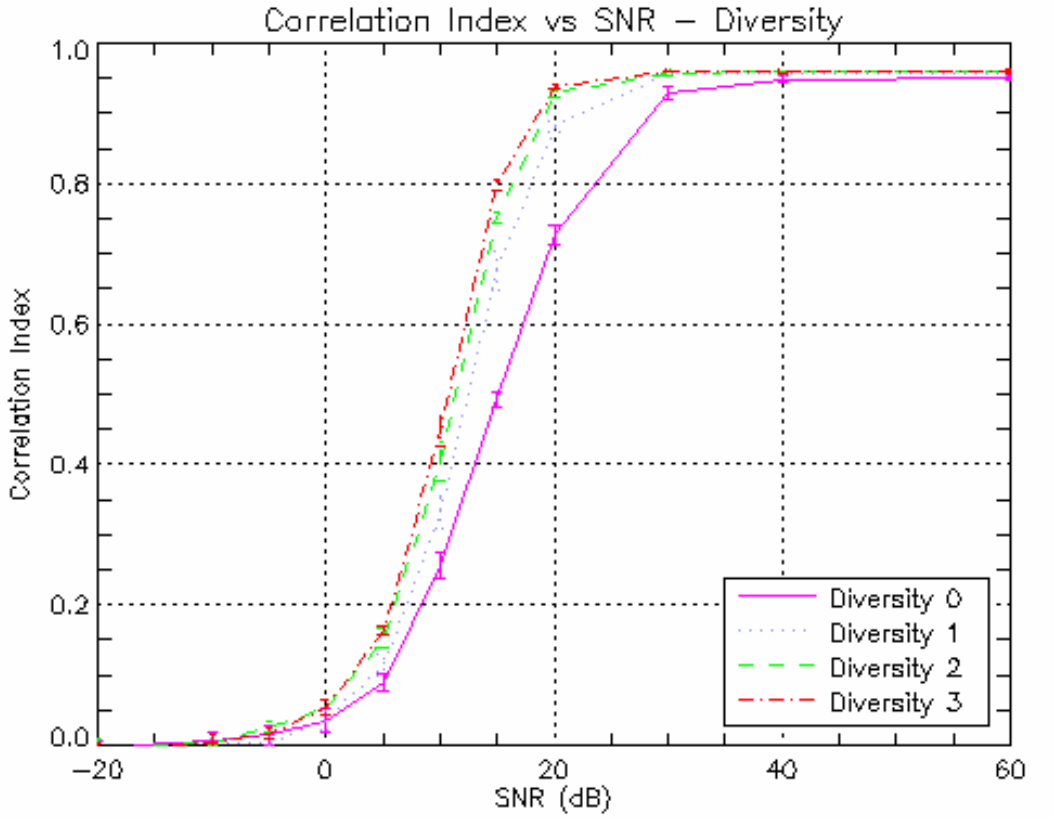
EEJ width = 15 km
Same EEJ parameters per layer

Voice Results: EEJ thickness



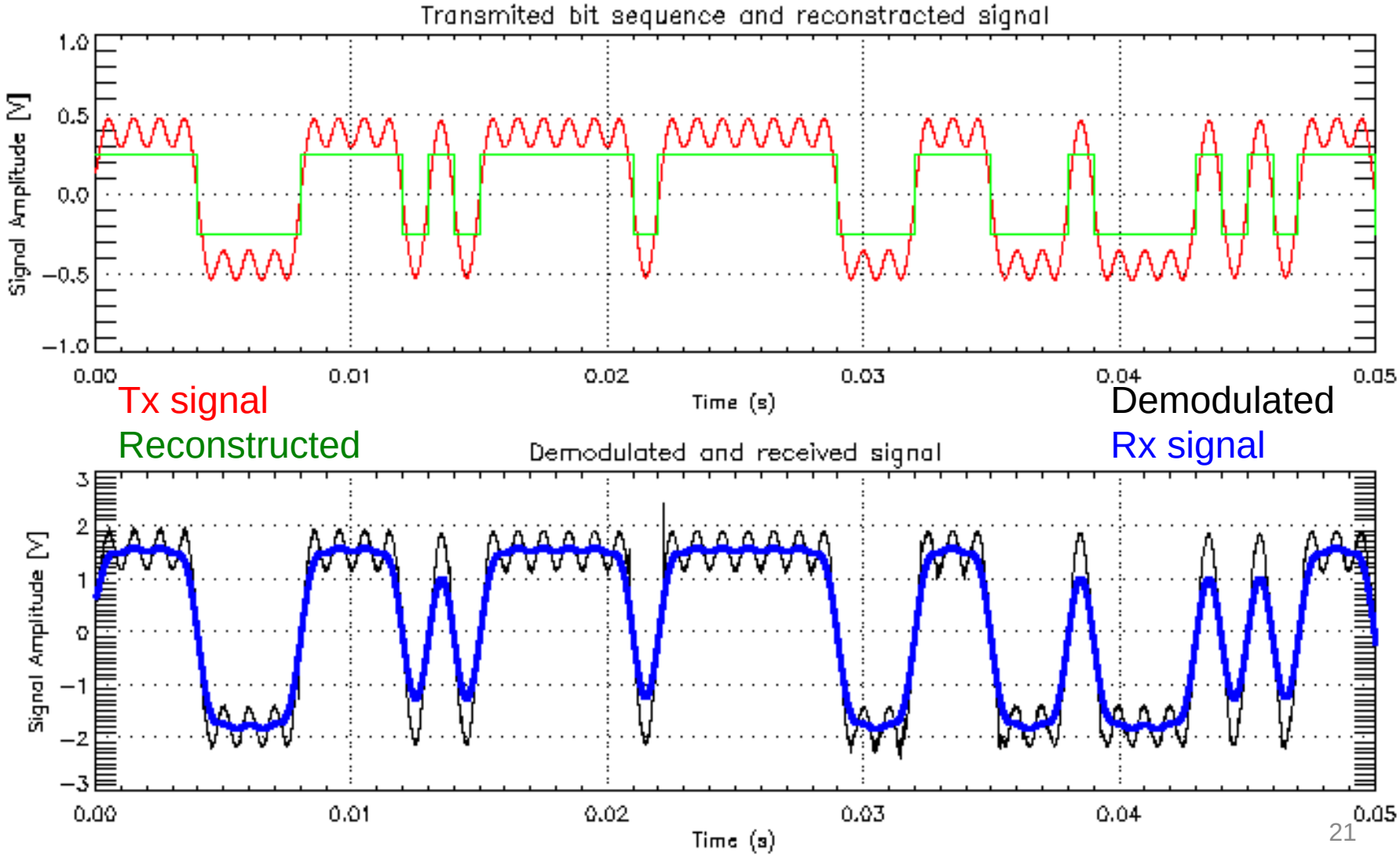
Same EEJ parameters per layer

Voice Results: Using Diversity

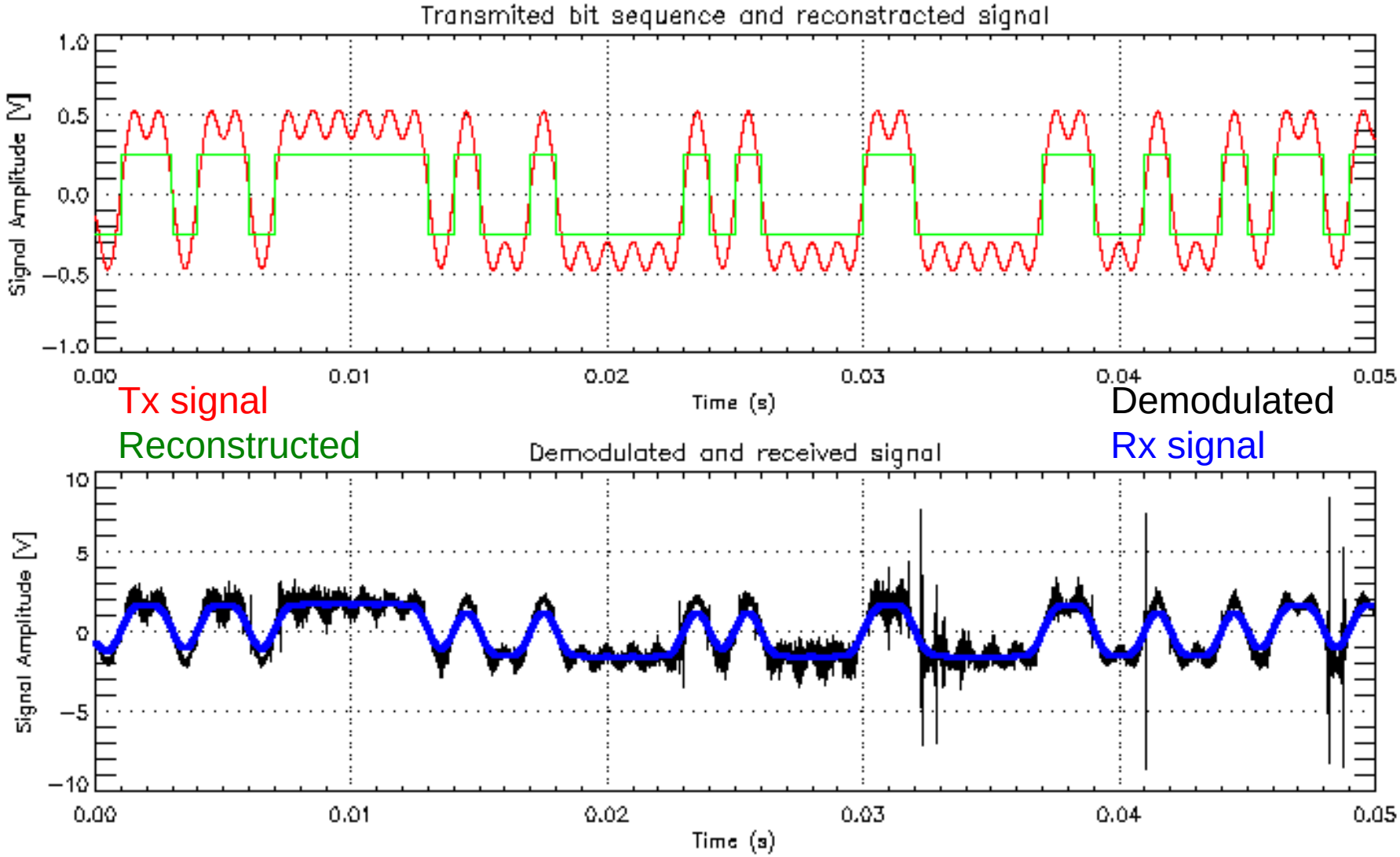


EEJ width = 15 km
Different EEJ parameters per layer

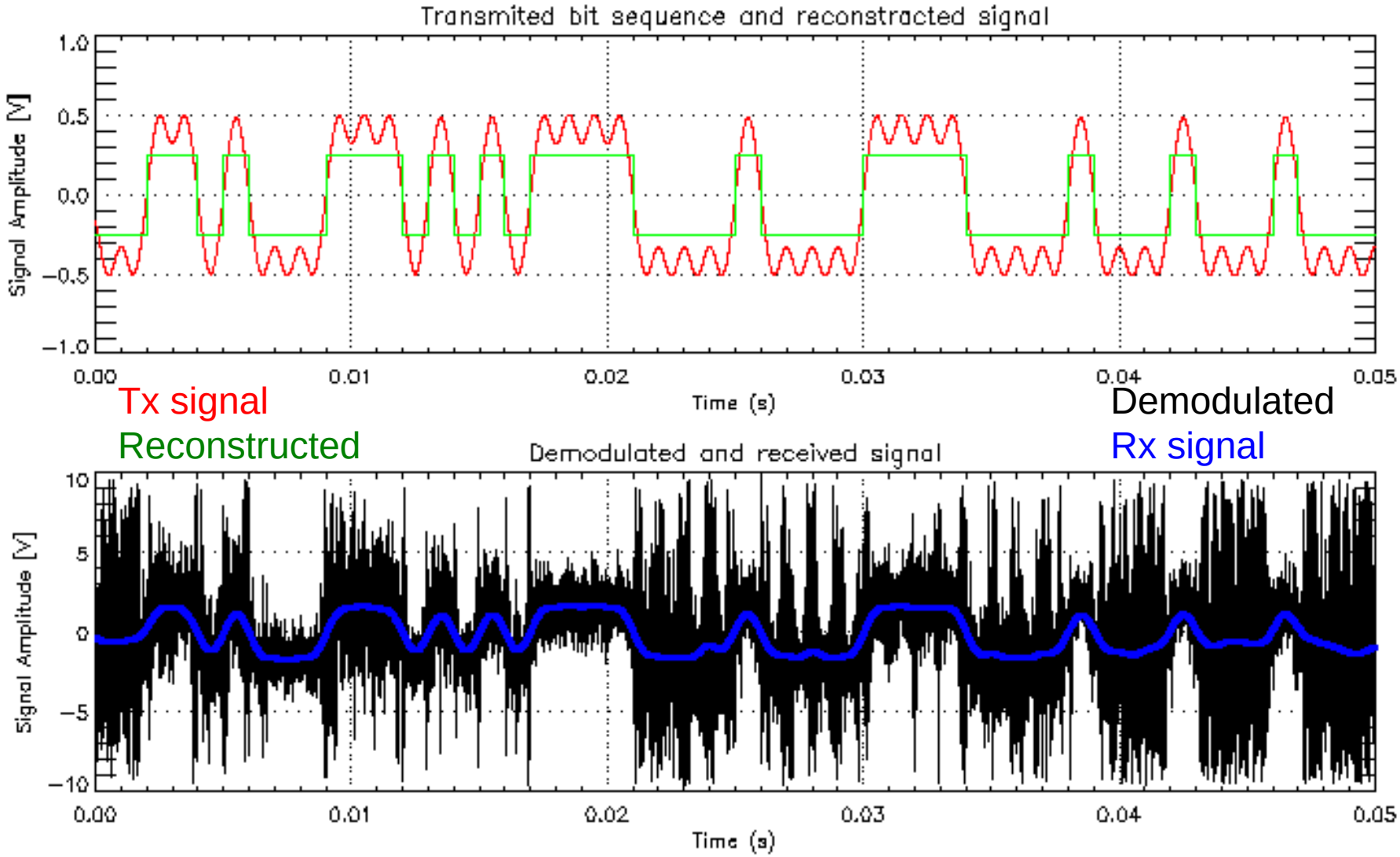
EEJ Simulator: Data
FM High SNR



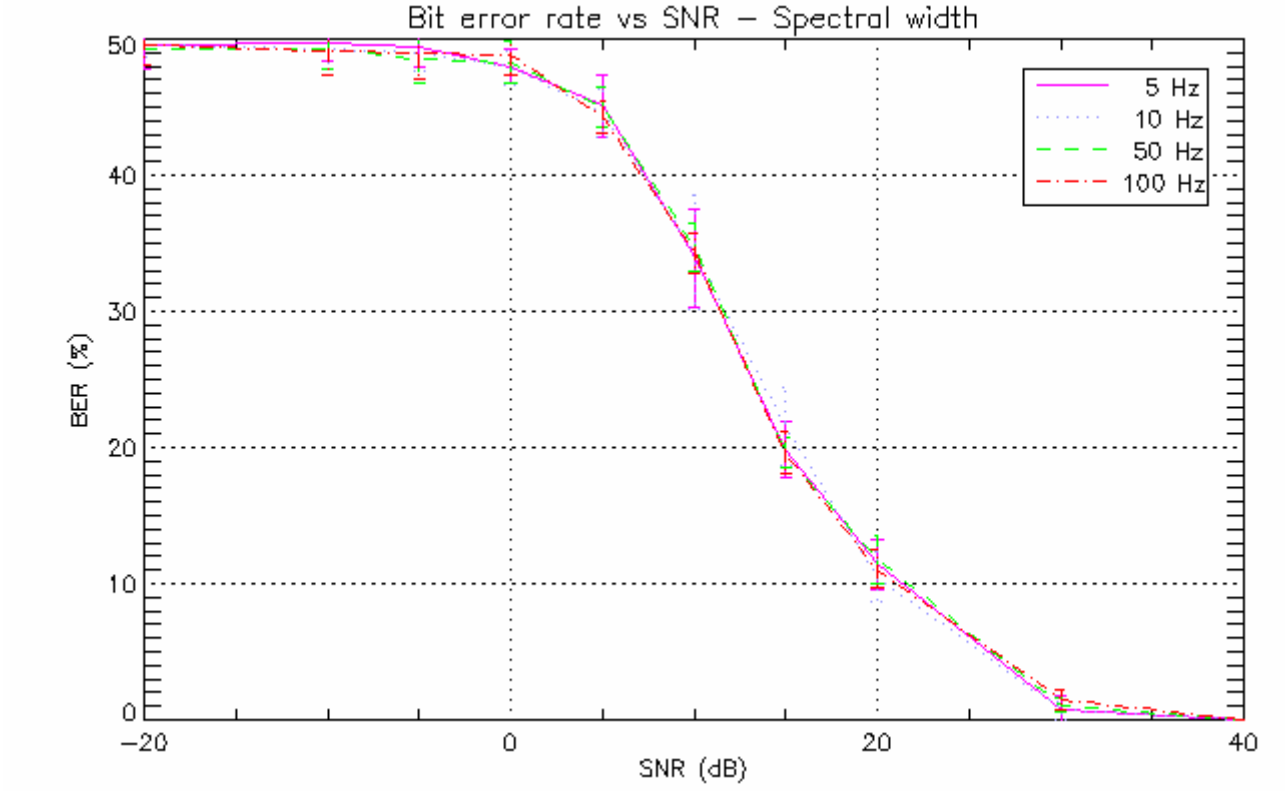
EEJ Simulator: Data
FM Medium SNR



EEJ Simulator: Data
FM Low SNR

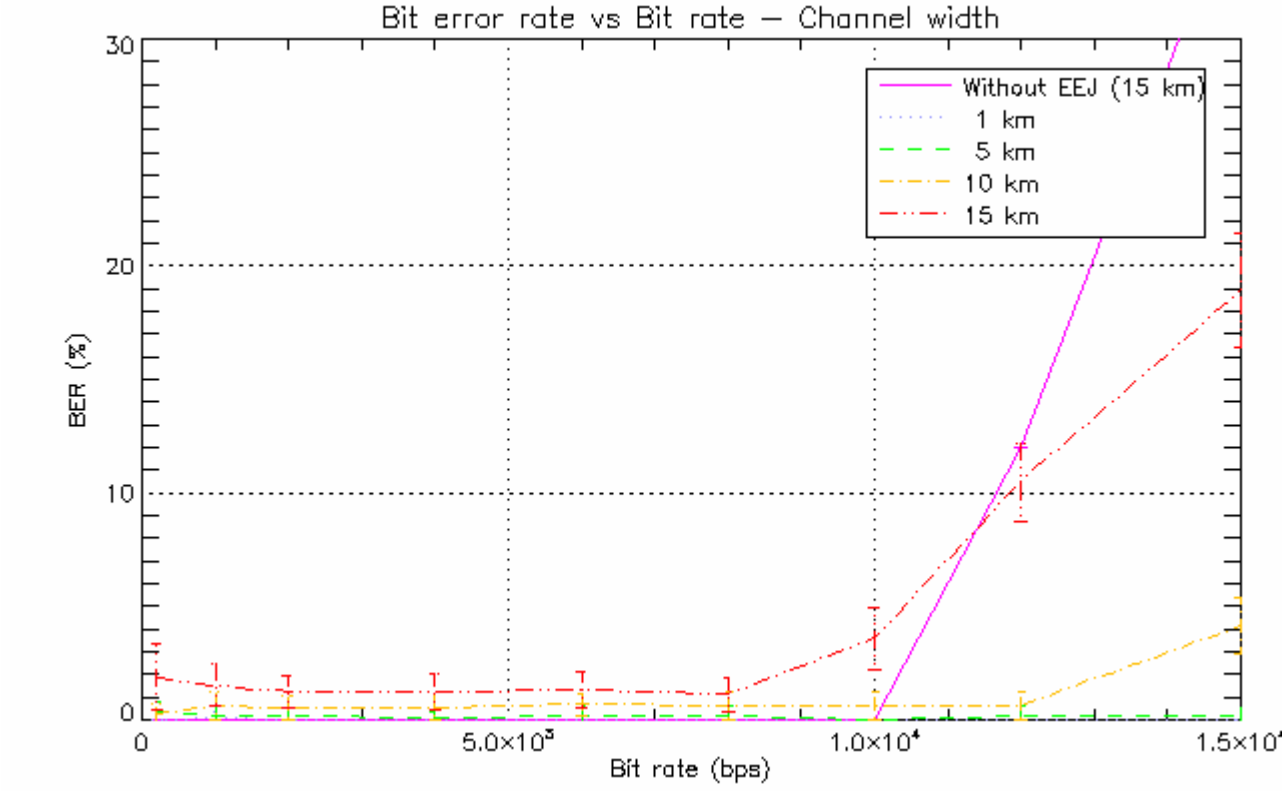


Data Results: BER vs. SNR vs. EEJ Spectral Width



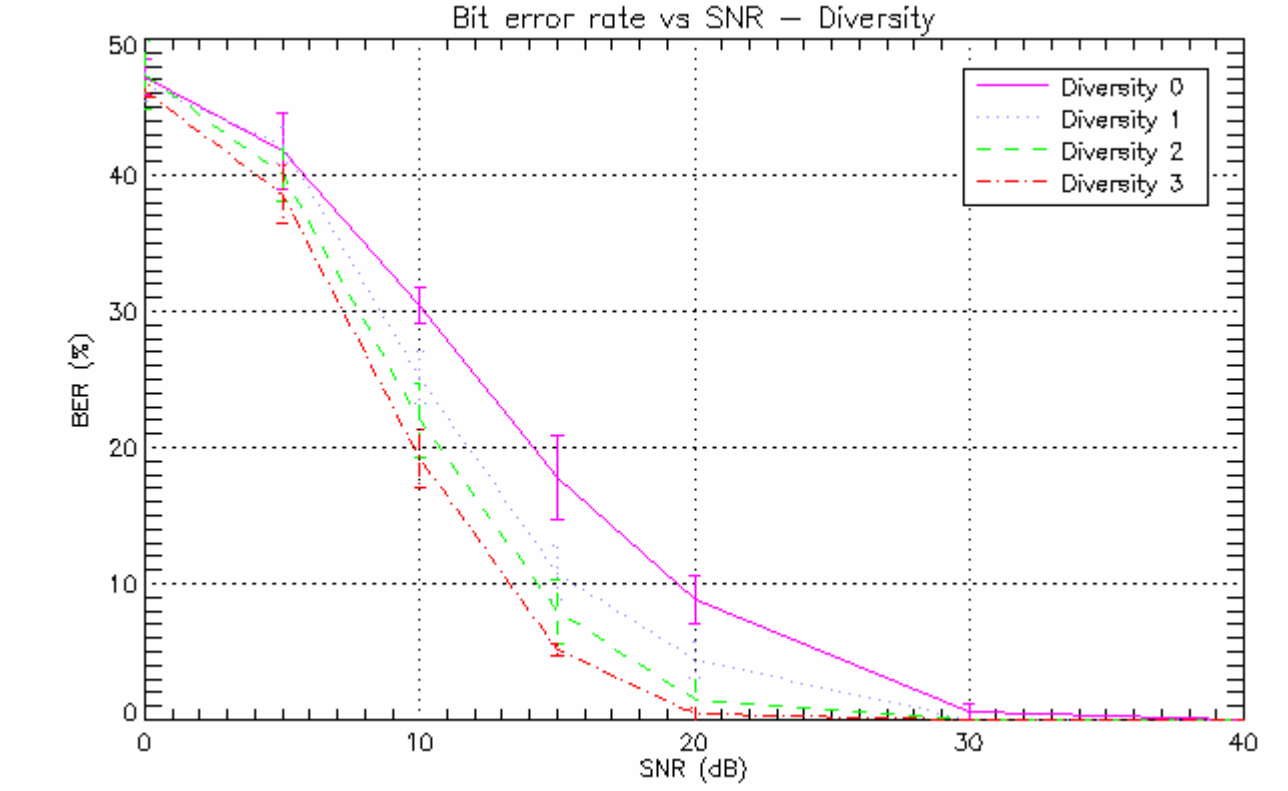
bps = 2000
EEJ width = 15 km
Same EEJ parameters per layer

Data Results: BER vs. bps vs. EEJ Thickness



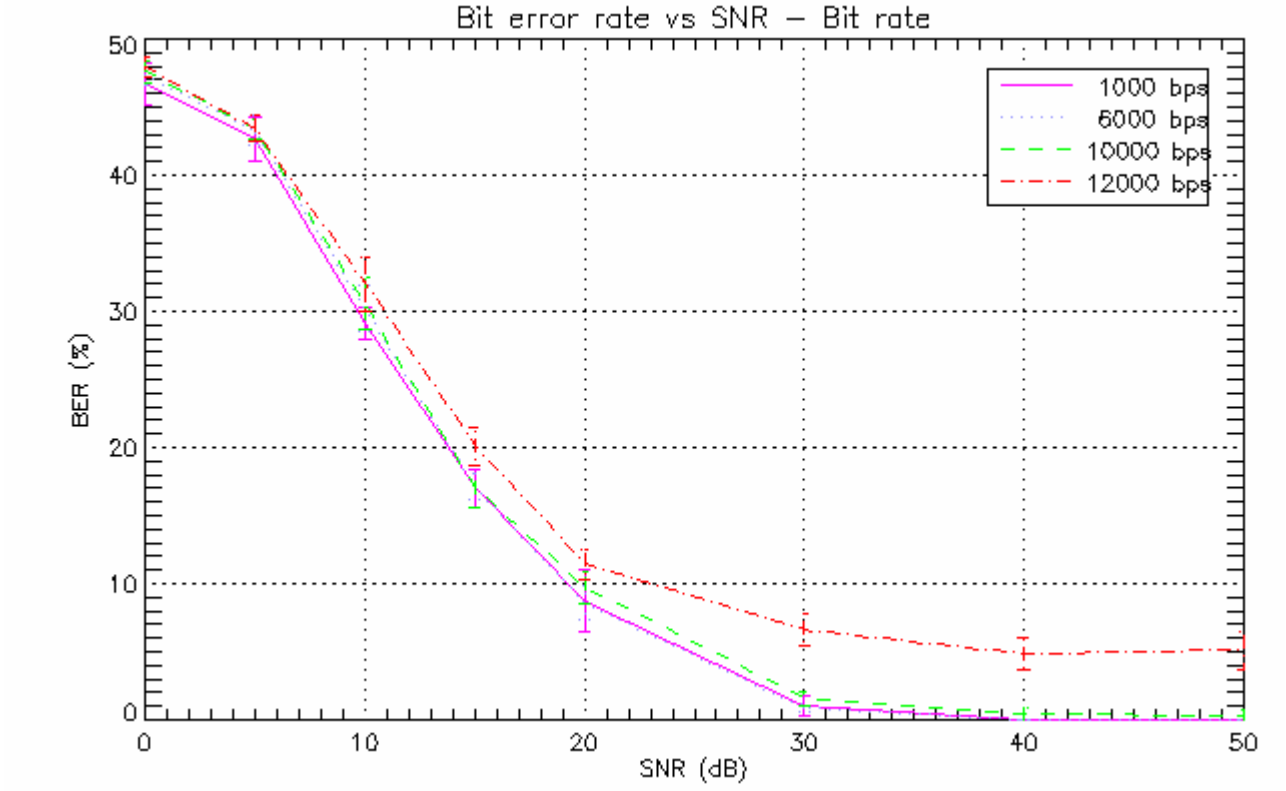
SNR = 30 dB
EEJ width = 15 km
Same EEJ parameters per layer

Data Results: BER vs. SNR vs. Diversity



bps = 2000
EEJ width = 15 km
Different EEJ parameters per layer

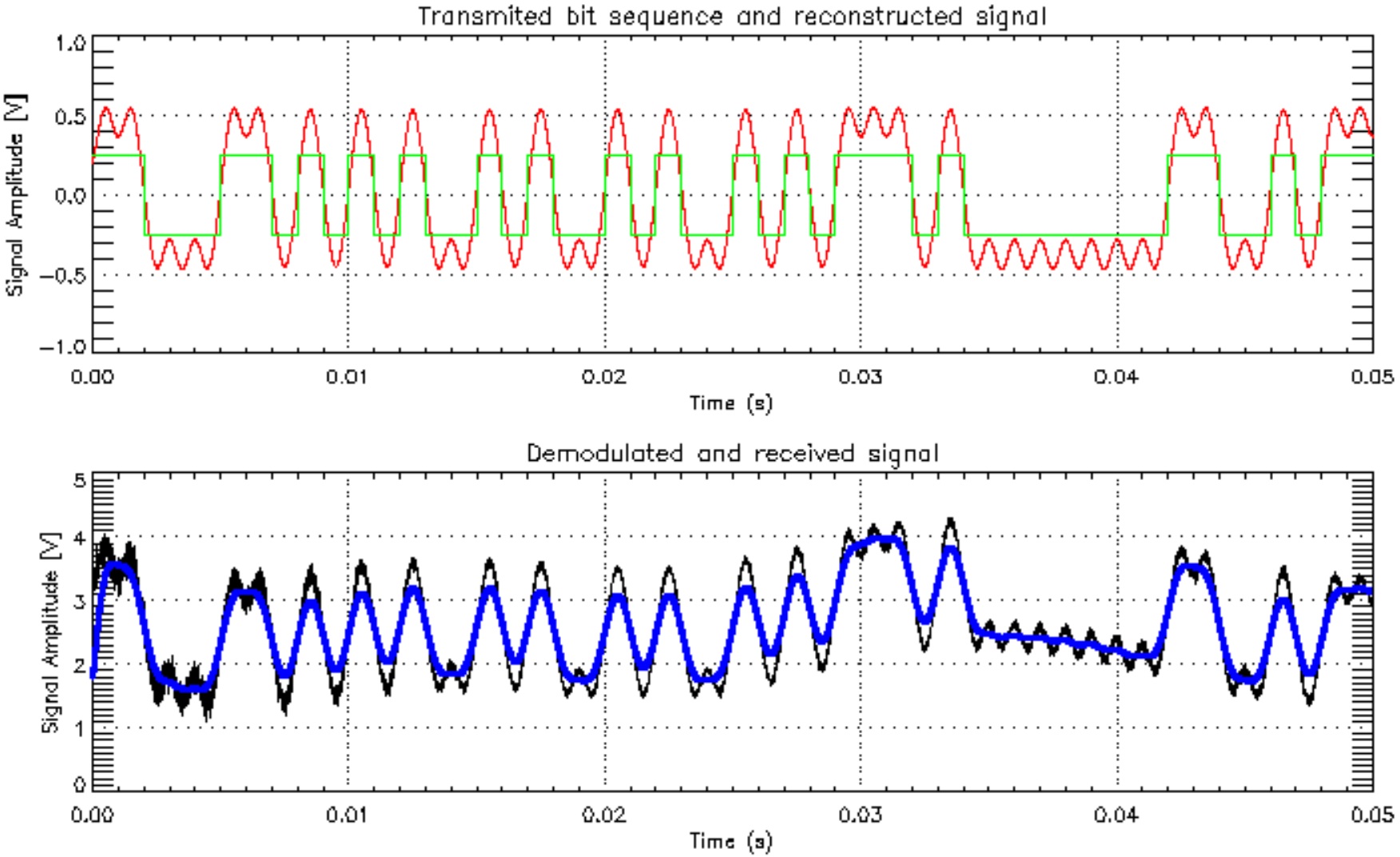
Data Results: BER vs. SNR vs. bps

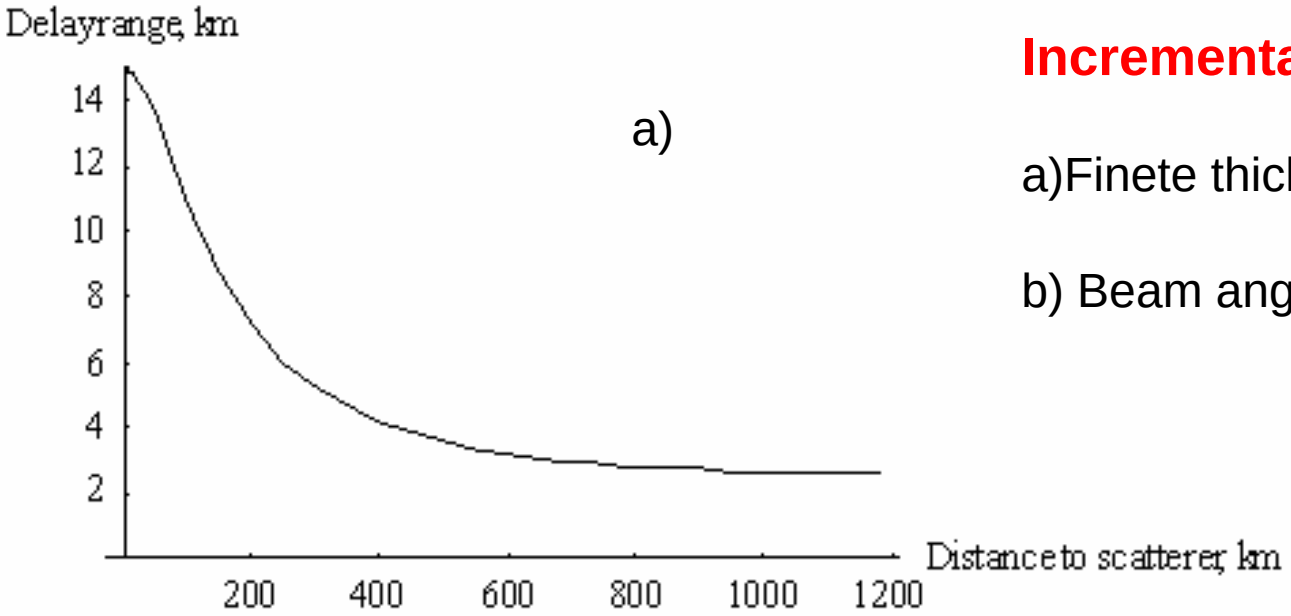


EEJ width = 15 km
Different EEJ parameters per layer

Summary

- The scattering properties of the electrojet permit VHF communications beyond the horizon.
- This is an asset that can be exploited by many equatorial developing countries
- A computer model has been developed permitting laboratory quantitative evaluation of different geometries and modulation techniques.
- Diversity techniques improves significantly the performance of a link.
- Channel capacity (BW) is limited by the dispersive nature of the scattering medium to ~10-30 kHZ


Transmited bit sequence and reconstructed signal
Signal Amplitude [V]
1.0
0.5
0.0
−0.5
−1.0
0.00
0.01
0.02
0.03
0.04
0.05
Time (s)
Demodulated and received signal
Signal Amplitude [V]
5
4
3
2
1
0
0.00
0.01
0.02
0.03
0.04
0.05
Time (s)

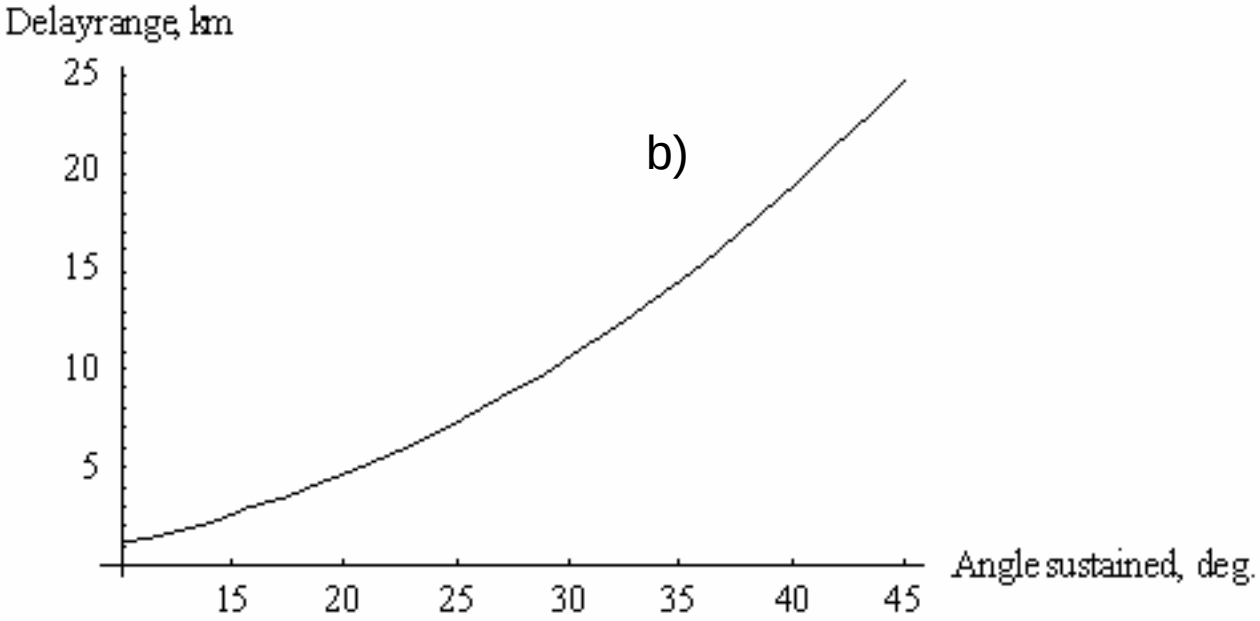


a)

Incremental delay due to:

a)Finete thickness of electrojet

b) Beam angle along electrojet at 300 km



b)