Ultra-Wideband Antenna Design for Transmission of a Digital Chaotic Signal

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Antenna Design

Introduction: The transfer of information between chaotic elements is of great interest in understanding the dynamics of large coupled networks. To explore the synchronization characterizations of such a network, we have begun examining methods for radio frequency signal transmission between chaotic oscillators. Coupling through radio transmission, rather than hard-wire connections, will allow for additional elements to be more easily added into the network. The individual oscillators are realized using a design with high-speed, commercially available logic gates that feed back to each other with independent delays. Each circuit operates in the ultra-high-frequency portion of the electromagnetic spectrum and satisfies the ultra-wide-band (UWB) criterion for a telecommunication device [1].

Ultra-Wideband (UWB):

A signal occupying over 500 MHz of the frequency spectrum. Or, a signal of fractional bandwidth $B_f > 0.2$, $B_f = 2\,(f_H - f_L) / (f_H + f_L)$ [2].

F_H = upper frequency of -10 dB,

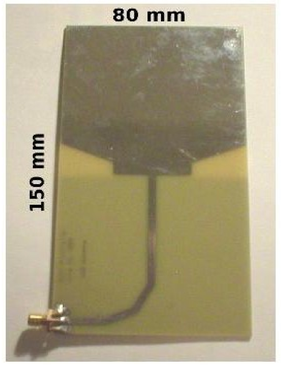
F_L = lower frequency of -10 dB.

Motivation:

• Design an antenna that transmits and recovers the information of such a digital chaotic device.

First Generation Design:

• Copper-trace monopole antenna printed on 80 mm x 150 mm FR4 dielectric.



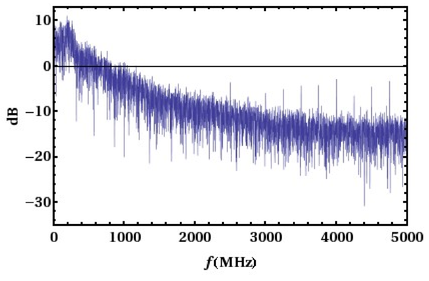
Raw Transmission

Chaotic Spectrum:

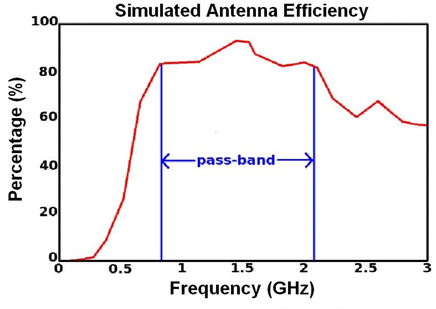
• Digital chaos has an UWB bandwidth from 30 MHz – 2.5 GHz.

• Antenna efficiency pass-band runs from 800 MHz – 2 GHz (covering only a portion of the oscillator's bandwidth) [3].

Digital Chaotic Frequency Spectrum



Simulated Antenna Efficiency



(% = $P_{radiation} / P_{input}$ x 100)

Problem:

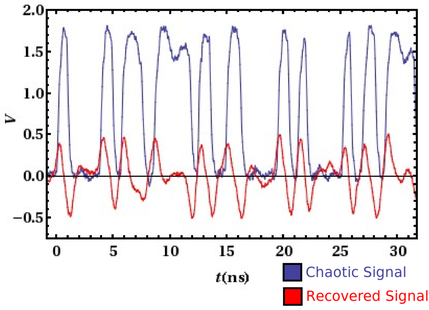
• Transmission filtered by antenna's pass-band.

• At distances larger than 1 cm, oscillations from filtering have amplitudes comparable to signal.

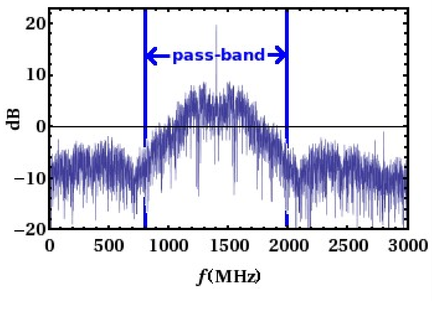
Solution:

• Shift spectrum of signal within antenna's pass-band.

Raw Close Range Transmission (< 1 cm)



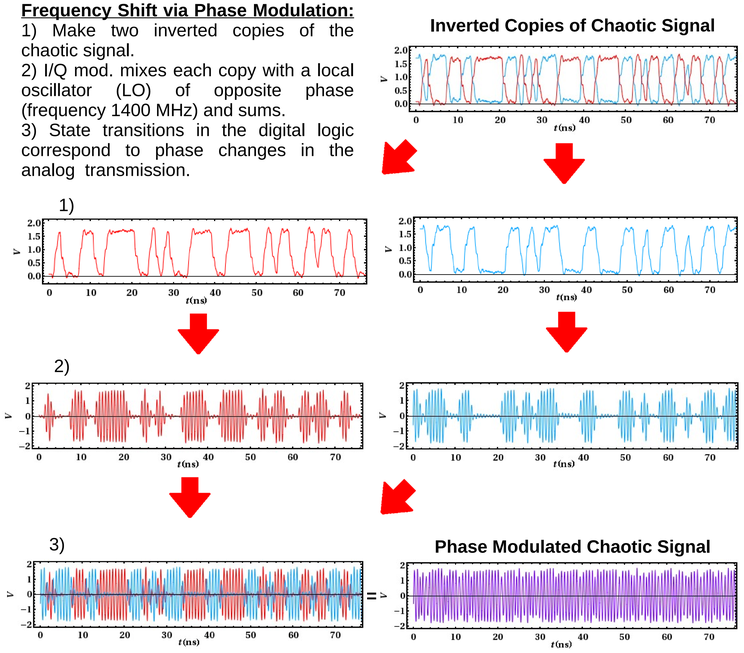
Simulated Chaotic Frequency Shift



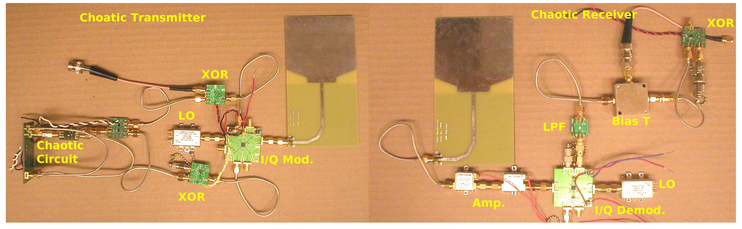
Modulation / Recovery

Frequency Shift via Phase Modulation:

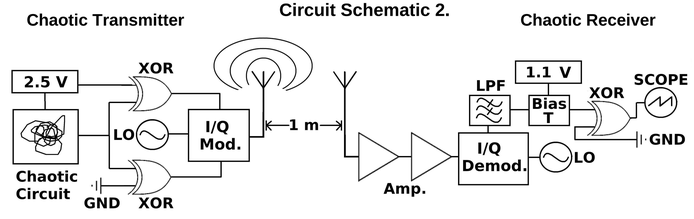
1) Make two inverted copies of the chaotic signal.
2) I/Q mod. mixes each copy with a local oscillator (LO) of opposite phase (frequency 1400 MHz) and sums.
3) State transitions in the digital logic correspond to phase changes in the analog transmission.



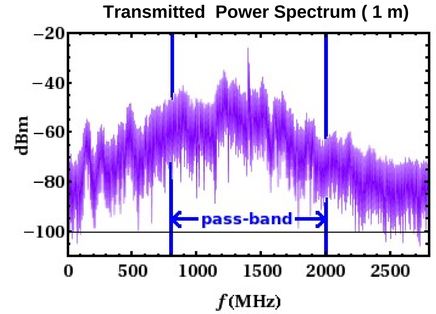
Circuit Schematic 1.



Circuit Schematic 2.



Transmitted Power Spectrum (1 m)

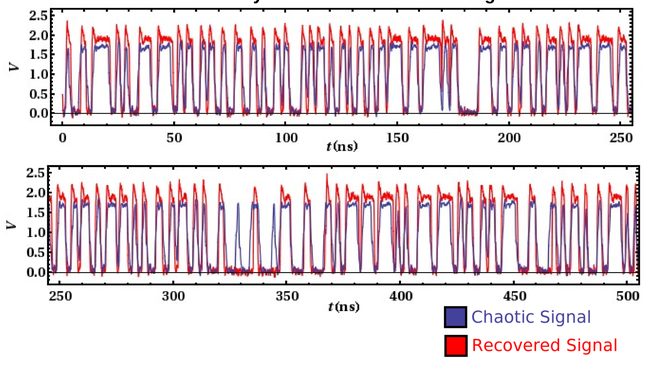


• Power concentrated in the antenna's pass-band with unfiltered transmission [4].

• I/Q demodulator recovers the primary components of the digital signal.

• Recovered waveform is filtered, biased, and reintegrated into a digital logic gate (Note: some short pulses are lost in transmission).

Recovery of Transmitted Chaotic Signal



Conclusions: Modulation aligns the chaotic frequency distribution within the first generation UWB antenna's pass-band, allowing for unfiltered transmission. A demodulation technique has been designed to successfully recover the transmitted chaotic signal. This transfer of information will be used to couple two or more of these elements in an area for further study.

Future Work

• Use the recovered signal to drive a coupled circuit.
• Incorporate a circulator for simultaneous transmission / recovery.
• Shift to FCC bandwidth (3.1-10.6 GHz) with modulation / smaller antenna.

References

1 - *Posters given by H.L.D. De S. Cavalcante (P62) and R. Zhang (P72).*
2 - Federal Communications Commission FCC02-48
3 - *IE3D Software Release 4.0, Zeland Software Inc., Fremont, California, USA.*
4 – *UWB Test Report*, Mlinarsky and Ziegler, www.octoscope.com, (2007)