Antennas Studies for UWB Radio

Program Review

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UWB Radio Antenna and Electromagnetics Tasks

- progress on original tasks -

1. Full-Wave Calculation of Receive Antenna Voltage

(arbitrary input voltage waveform, antenna types, angle of incidence, load impedance, polarization, and T/R matching/shaping networks)

2. Modeling of Antenna Link with Multipath

(model LOS and multipath signals, variable amplitude, possible polarity reversals)

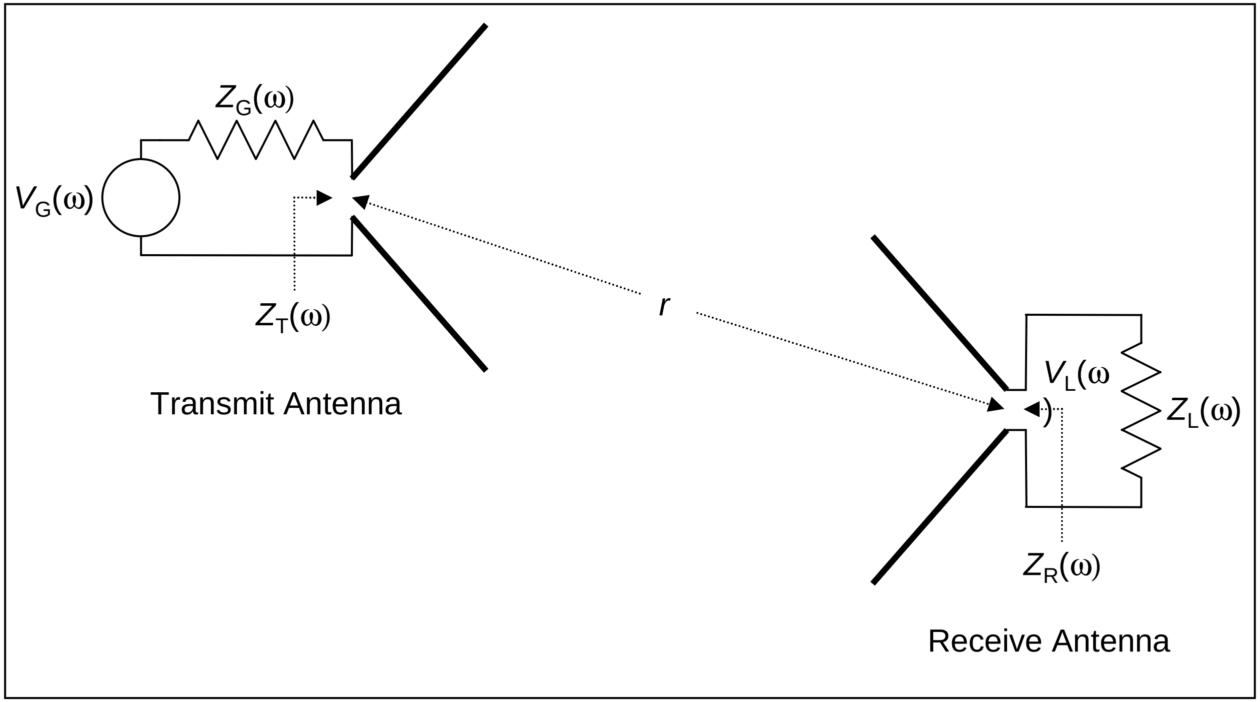
3. Optimization of Transmit/Receive Link

(define "optimum" metric, pulse shaping constraints, power spectral density shaping, antenna efficiency, antenna patterns)

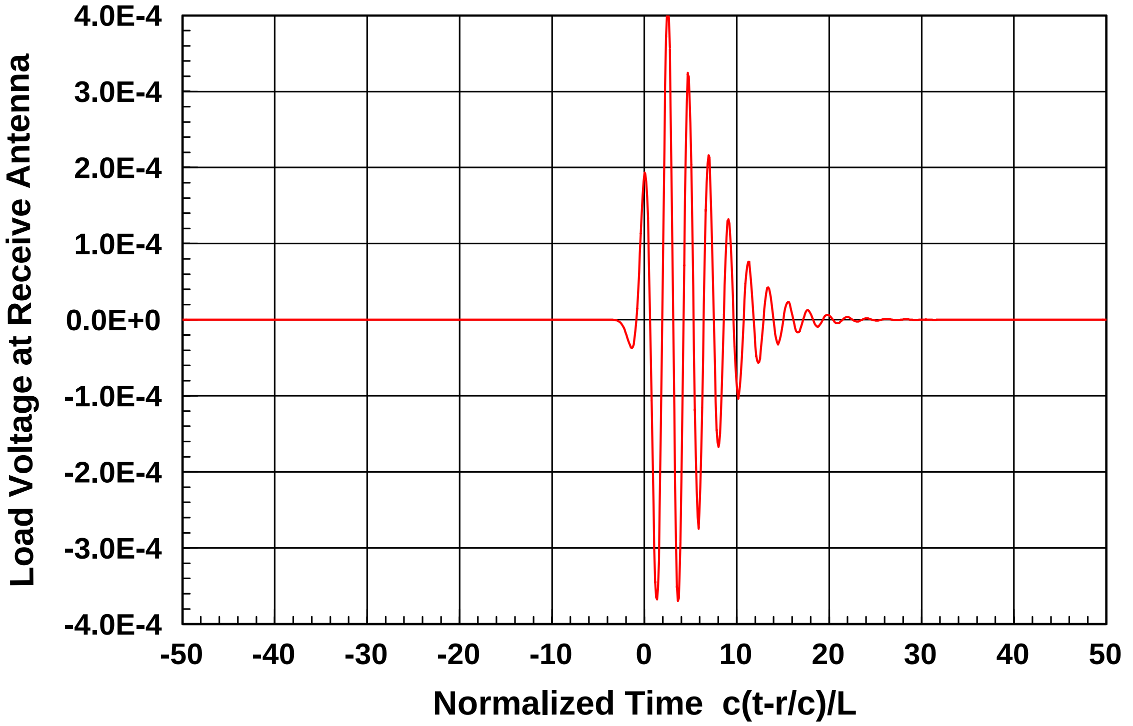
UWB Antenna Work Since 9/01

- Analytical results for pulse transmission between electrically small dipoles, loops
- Numerical (MoM) results for pulse transmission between dipoles, including resistive loading
- Numerical (MoM) formulation for pulse transmission between arbitrary wire antennas
- Measurements of transfer function between monopole antennas
- Optimization of waveforms for UWB radio transmission
- Publication: "*Waveform Optimizations for Ultra-Wideband Radio Systems*", by D. M. Pozar, accepted for publication in IEEE Trans. Antennas and Propagation.

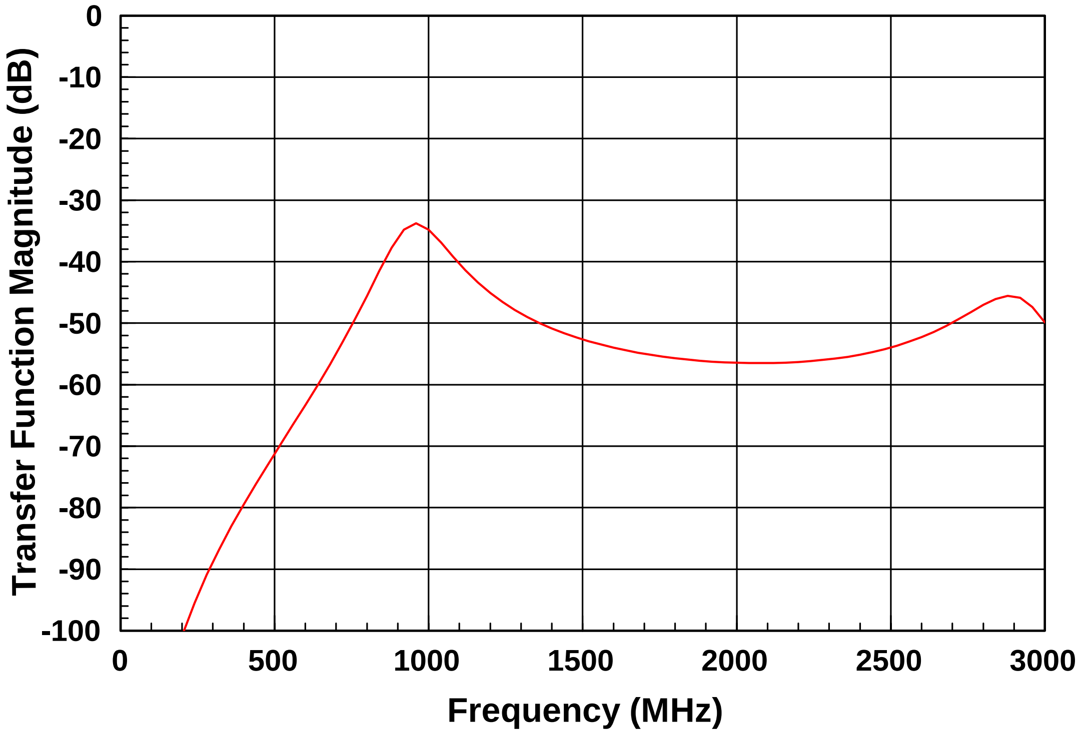
Frequency domain model of transmit and receive antennas for a UWB radio system.



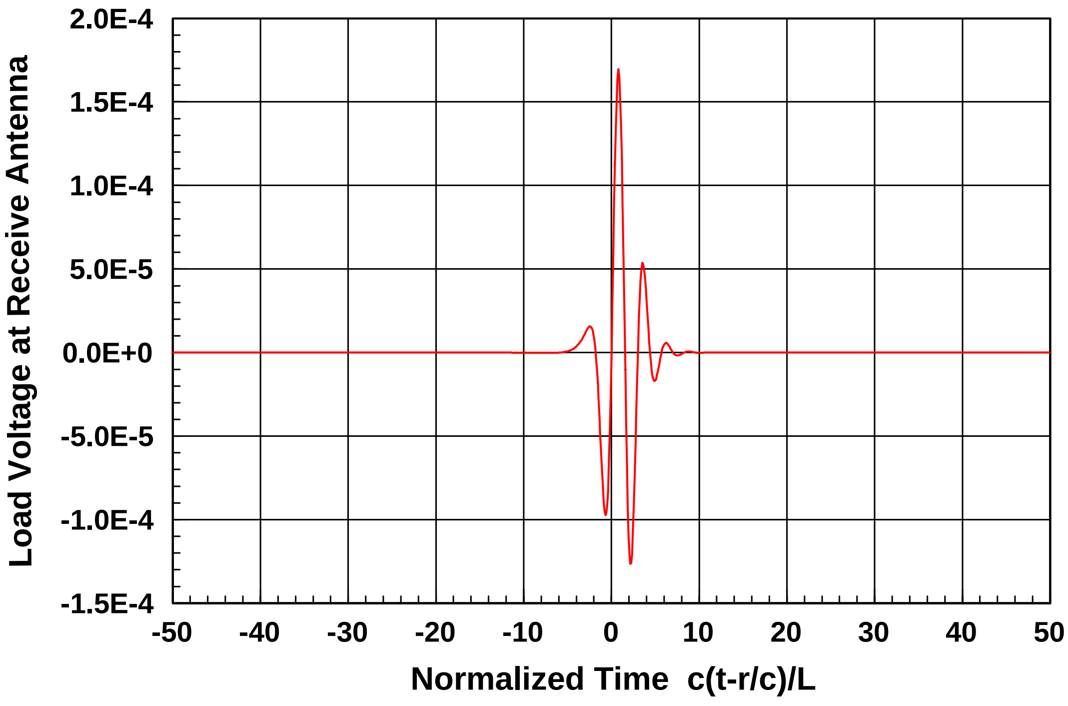
Transient Radiation and Reception for Lossy Dipoles . . .



Received load voltage for lossless transmit and receive dipoles. Dipole length =15 cm, σ = 5.8E7 S/m, gaussian input pulse, Z_g=Z_L=50 Ω.



Transfer function magnitude vs. frequency for dipoles of previous slide.



Received load voltage for lossy transmit and receive dipoles. Dipole length =15 cm,

σ = 1.0E4 S/m, gaussian input pulse, $Z_g = Z_L = 50\ \Omega$.

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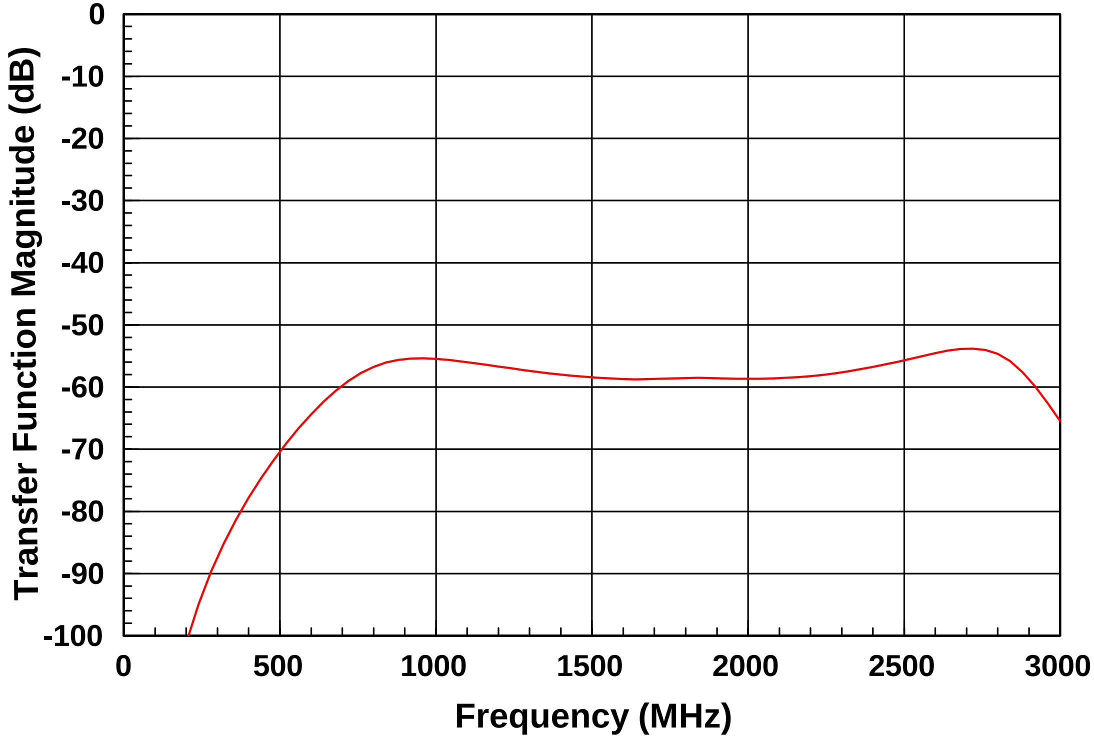


Transfer function magnitude vs. frequency for dipoles of previous slide.

Optimizations of transient waveforms and signals for UWB radio systems

- Variational solutions for the optimum transmit antenna generator waveform required to:
    - maximize receive antenna voltage amplitude (with constrained input energy and bandwidth)
    - provides the “sharpest” received antenna voltage waveform (with constrained input energy and bandwidth)
    - maximize received energy (with an inequality constraint on the radiated power spectral density)
- Results are derived for arbitrary antennas
- Effects of generator and load impedances are included
- Rigorous EM solutions via moment method
- Closed-form results for short dipole antennas for some special cases.

Waveform Optimization Theory . . .

Transfer function between receiver load voltage and generator voltage is defined as:

$$V_L(\omega) = H_{LG}(\omega) V_G(\omega) e^{-j\omega r/c}$$

Transfer function between radiated field and generator voltage is defined as:

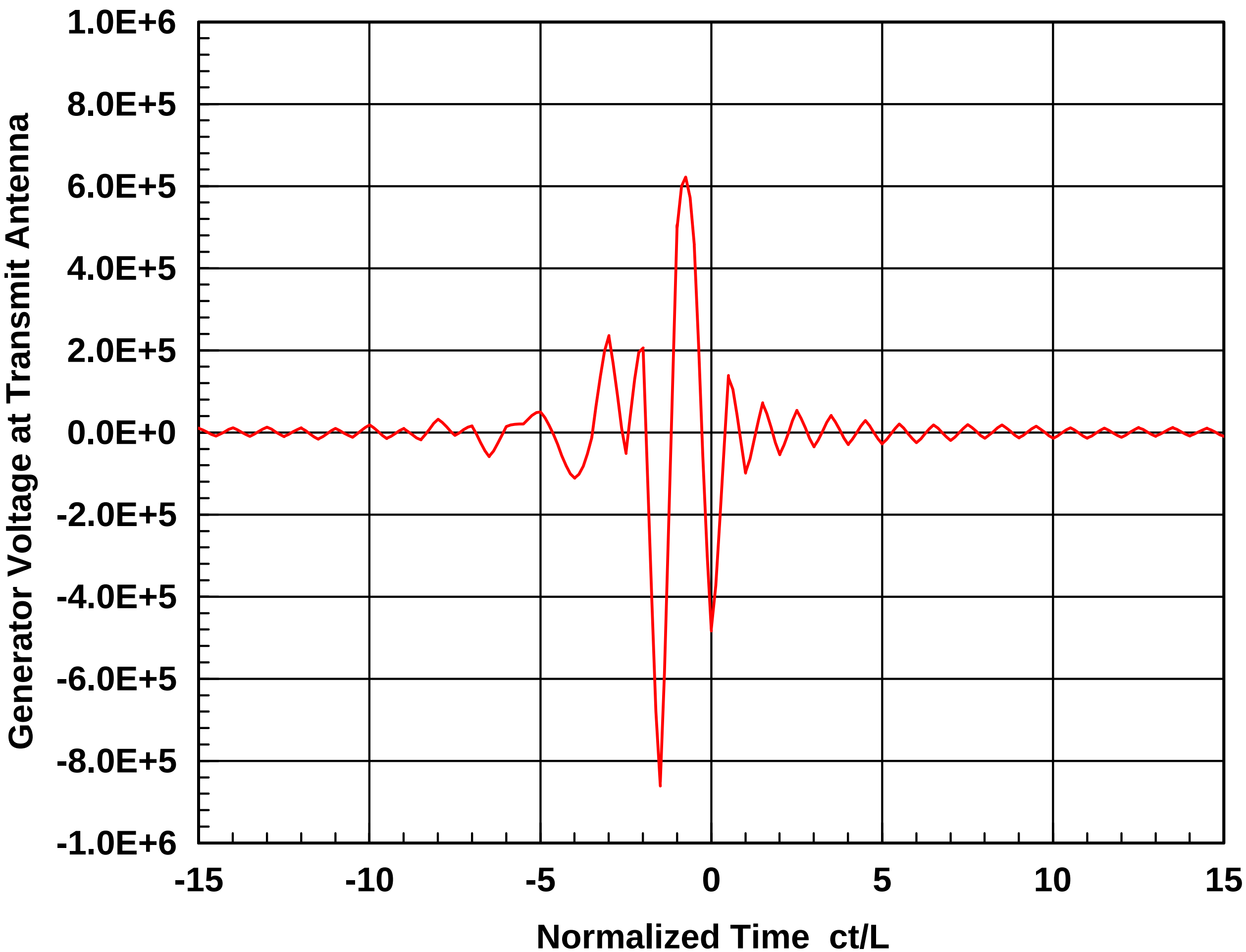
$$\bar{E}(\omega) = \bar{F}_{EG}(\omega) V_G(\omega) e^{-j\omega r/c}$$

Open-circuit receive voltage induced by incident electric field:

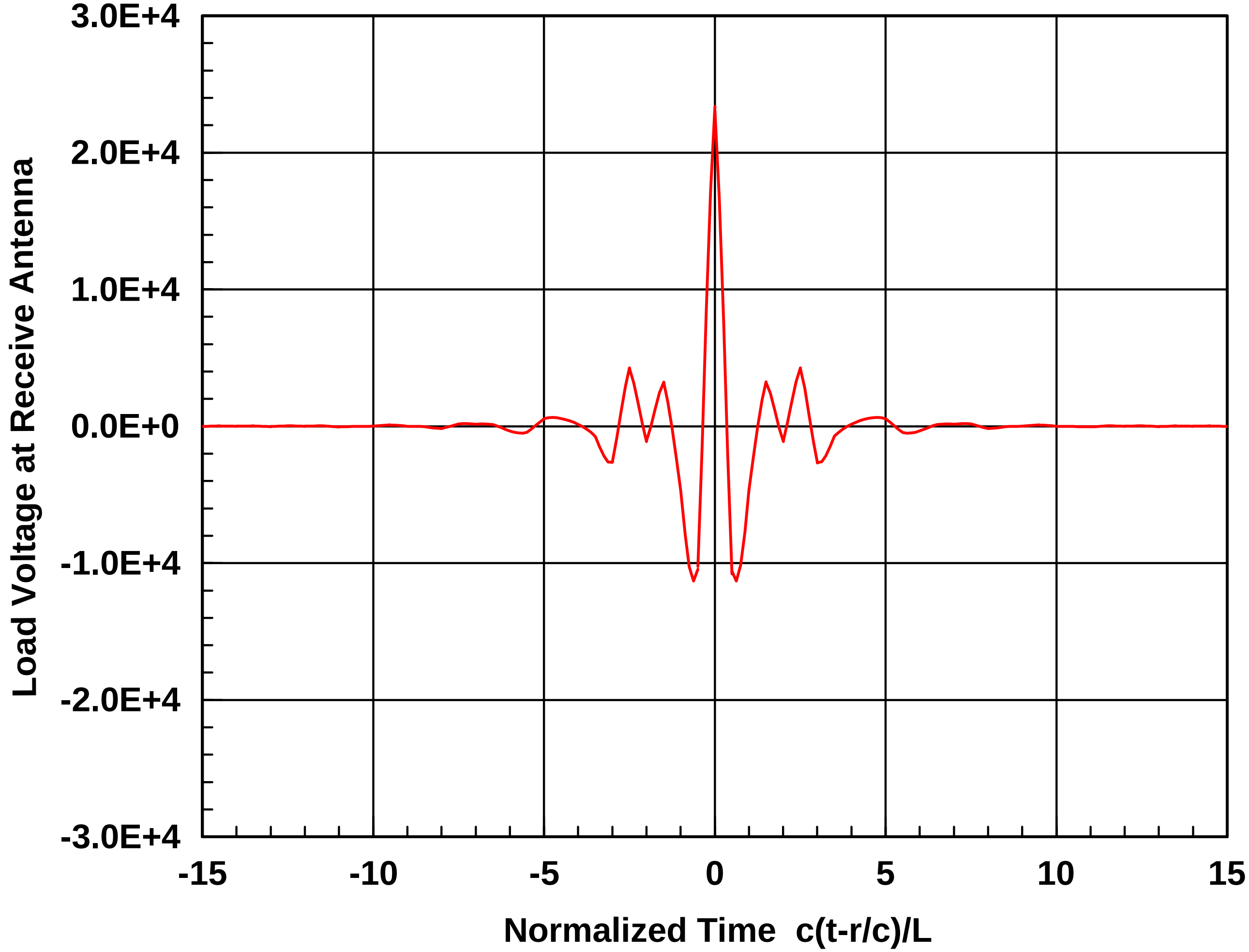
$$V_{oc}(\omega) = \bar{h}(\omega) \cdot \bar{E}(\omega)$$

Time-domain voltage at receiver in terms of generator voltage $(t' = t - r/c)$

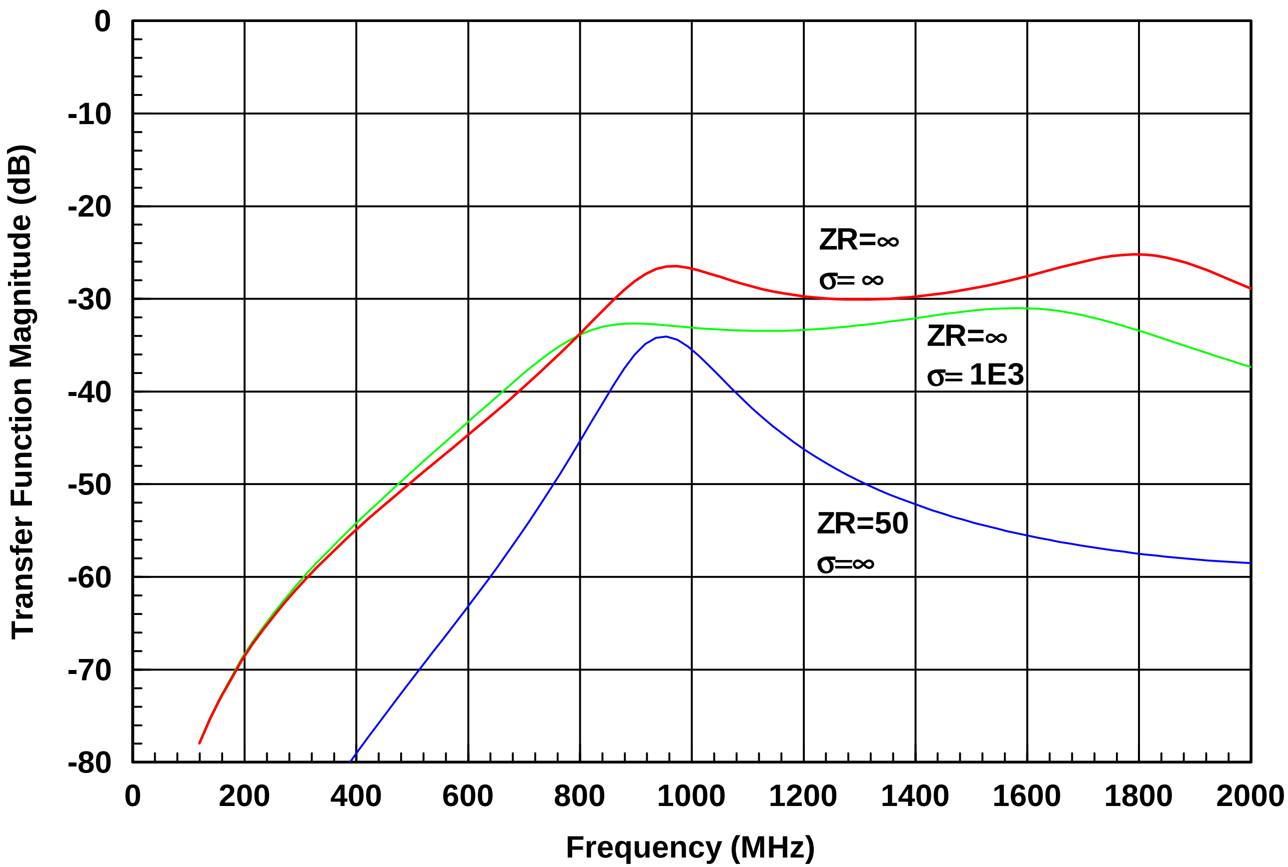
$$v_L(t') = \frac{1}{2\pi} \int_{BW} H_{LG}(\omega) V_G(\omega) e^{j\omega t'} d\omega$$



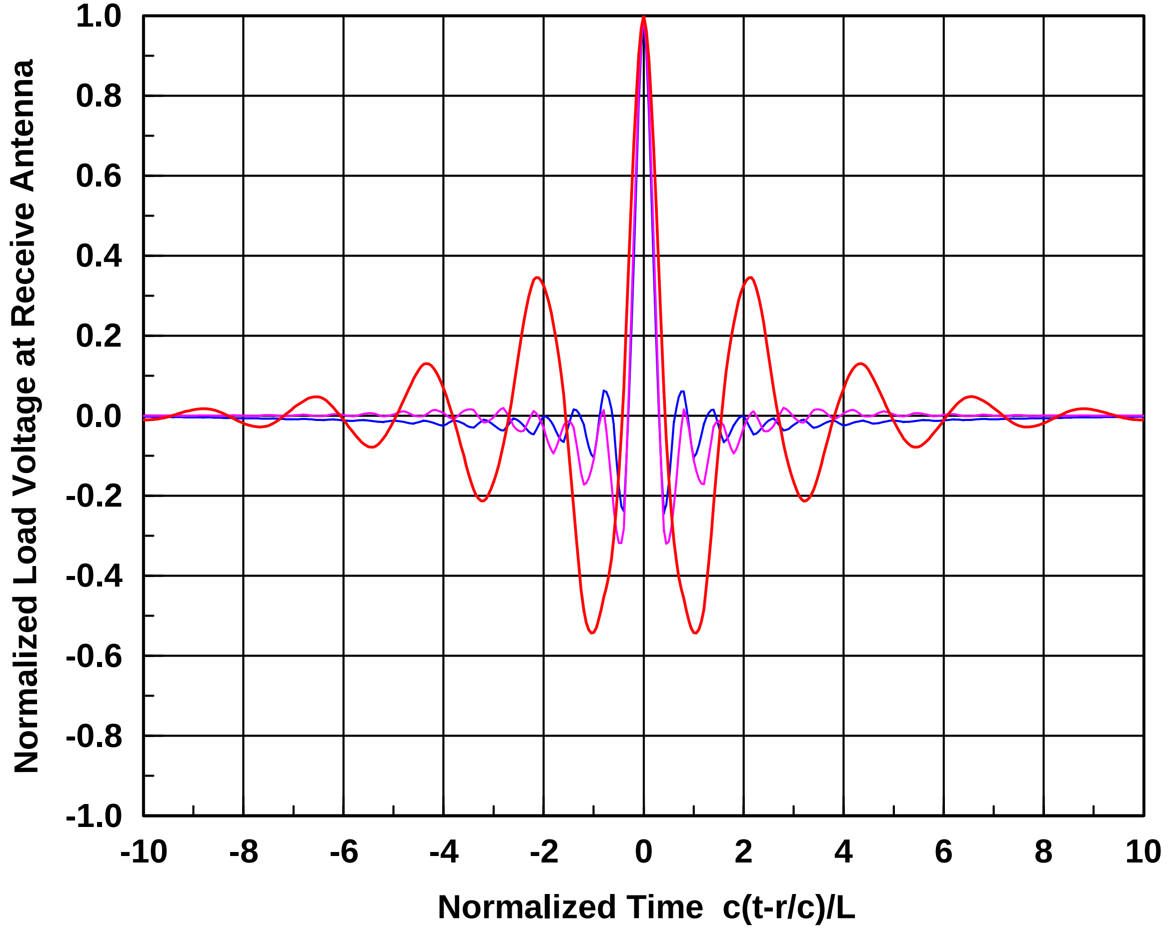
Generator voltage waveform to maximize receive voltage amplitude for dipoles with L= 15 cm, a = 0.02 cm, σ = 1000 S/m, Z_T = 50 Ω, $Z_R = \infty$. Available generator energy constrained to 1 Joule; bandwidth is 2 GHz.



Resulting optimized receive antenna voltage waveform for the antenna parameters of previous figure.



Voltage transfer function magnitude versus frequency for a pair of dipoles with L = 15 cm, a = 0.02 cm, Z_T = 50 Ω, for various conductivities and receiver load impedances.



Normalized receive voltage versus time for optimized waveform "sharpness" with various values of v_0 for lossy dipoles having L = 15 cm, a = 0.02 cm, σ = 1.0E4 S/m, Z_T = 50 Ω, and $Z_R = \infty$. The signal bandwidth is 2 GHz, and the constrained input energy is W_{in} = 1 Joule. Red: v_0 = 5381, Purple: v_0 = 3000, Blue: v_0 = 500.

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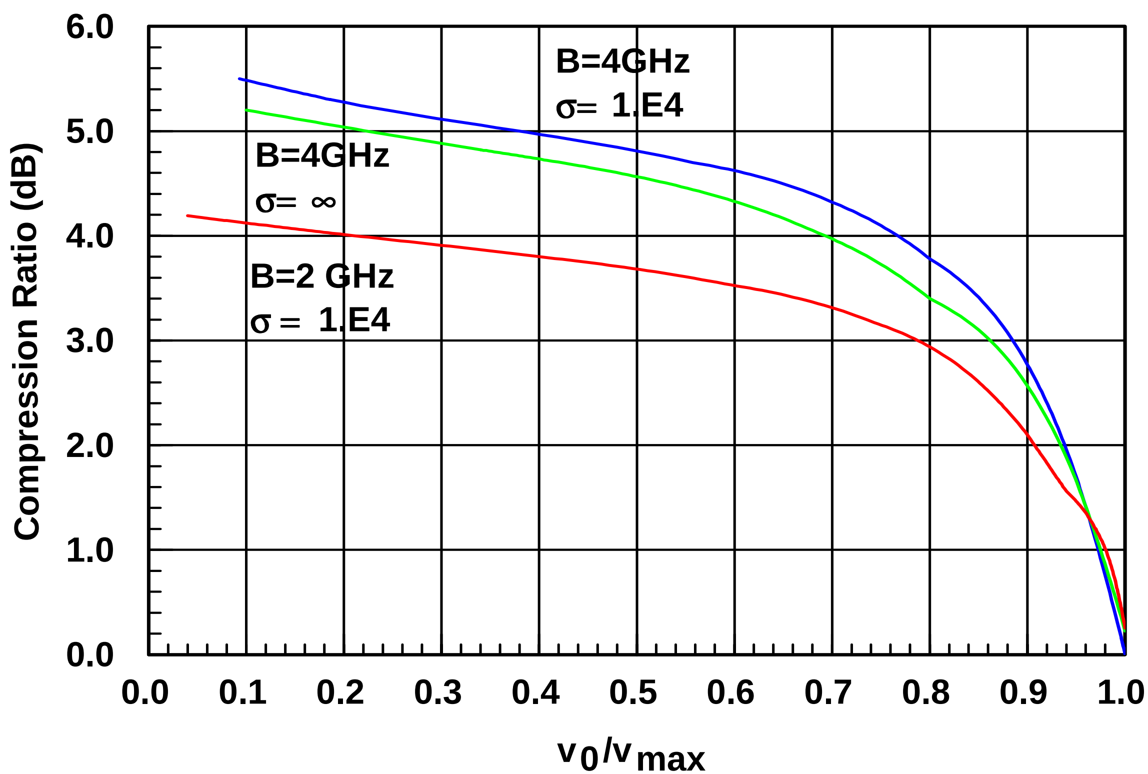
Compression ratio:

$$CR = 10\log\frac{W_{rec-\max} v_0^2}{W_{rec} v_{\max}^2}$$



Compression ratio versus normalized constrained receiver voltage for dipoles defined in previous figures.

Effects of Recent FCC Ruling on UWB . . .

(limiting UWB spectrum to 3.1 – 10.6 GHz)

Effect on Antennas: **GOOD**

Small antennas radiate higher frequencies more efficiently.

Effect on Propagation: **BAD**

Propagation characteristics of higher frequencies are less desirable.

Future Work

- Exercise optimum solutions with new FCC frequency range
- Complete general wire antenna analysis
- Exercise wire analysis for practical antennas
- Test a commercial UWB radio with various antennas
- Explore fractal antennas for UWB
- Begin modeling of multipath with wire antenna model
- Report on results for UWB link budget