Analysis and Simulation of UWB Interference Effects

NETEX Industry Day Briefing

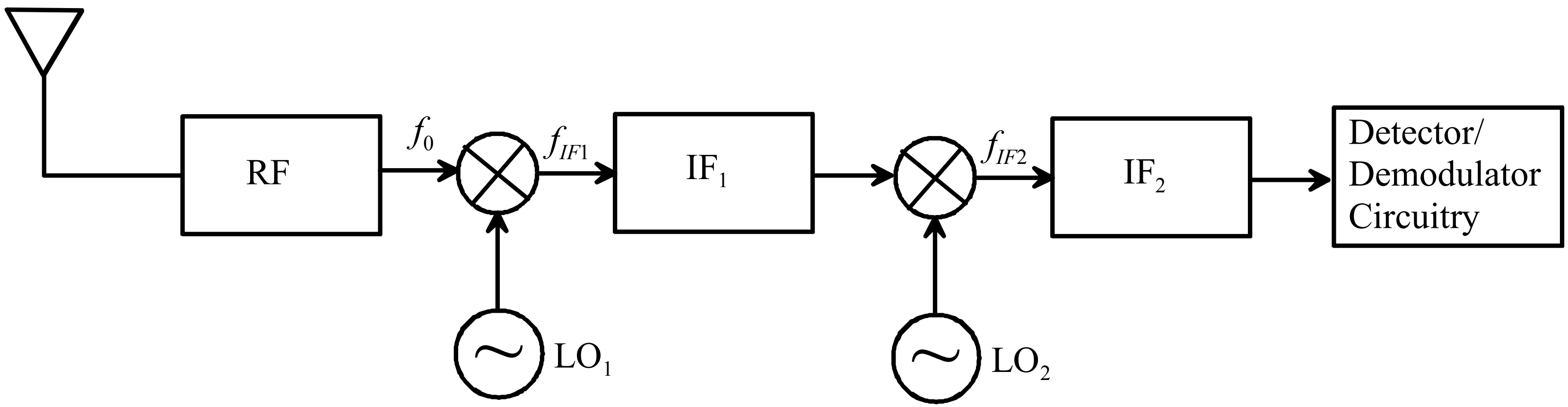
April 7, 2003

Dr. Jay Padgett
jpadgett@telcordia.com
Senior Research Scientist
Advanced Wireless Signal Processing
Telcordia Technologies

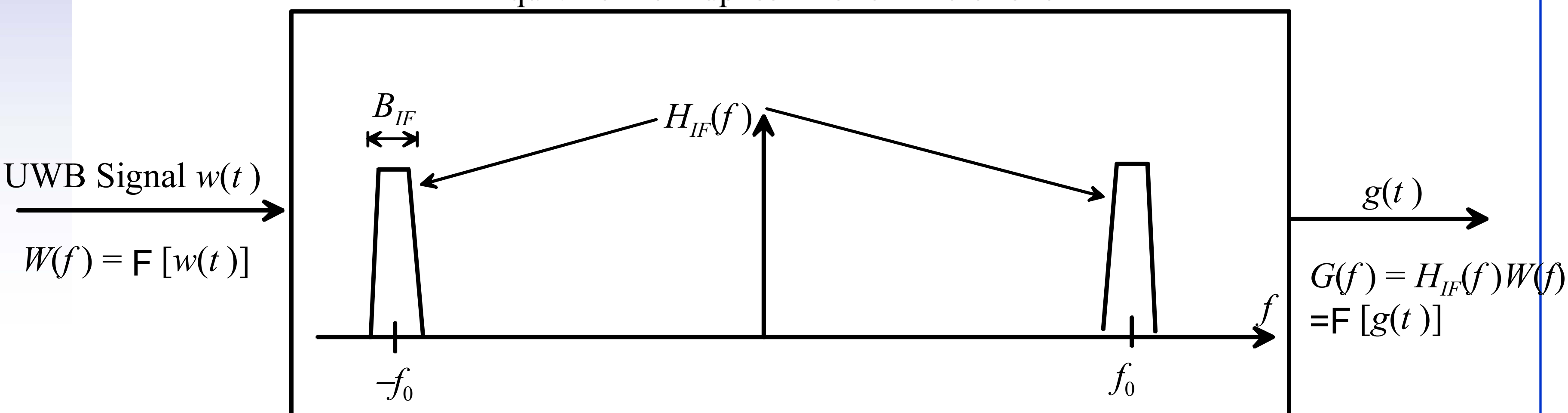
Overview

- Purpose: Develop mathematical models and simulations to analyze the impact of UWB signals on narrowband receivers
- Main components
  - Detailed analysis of UWB power spectral density (PSD)
    - Shows the distribution of UWB transmit power over frequency
    - Depends on (1) pulse energy spectral density and (2) pulse repetition discipline and amplitude modulation
    - PSD is important because UWB interference within receiver passband determines interference effects
  - Temporal simulation of UWB interference waveform at the output of the final IF filter
  - Models for calculating impact of UWB interference on different receiver types (FM, coherent and noncoherent FSK, PSK).
  - UWB-to-legacy system impact analysis, accounting for separation distance, propagation, required SIR levels, etc.

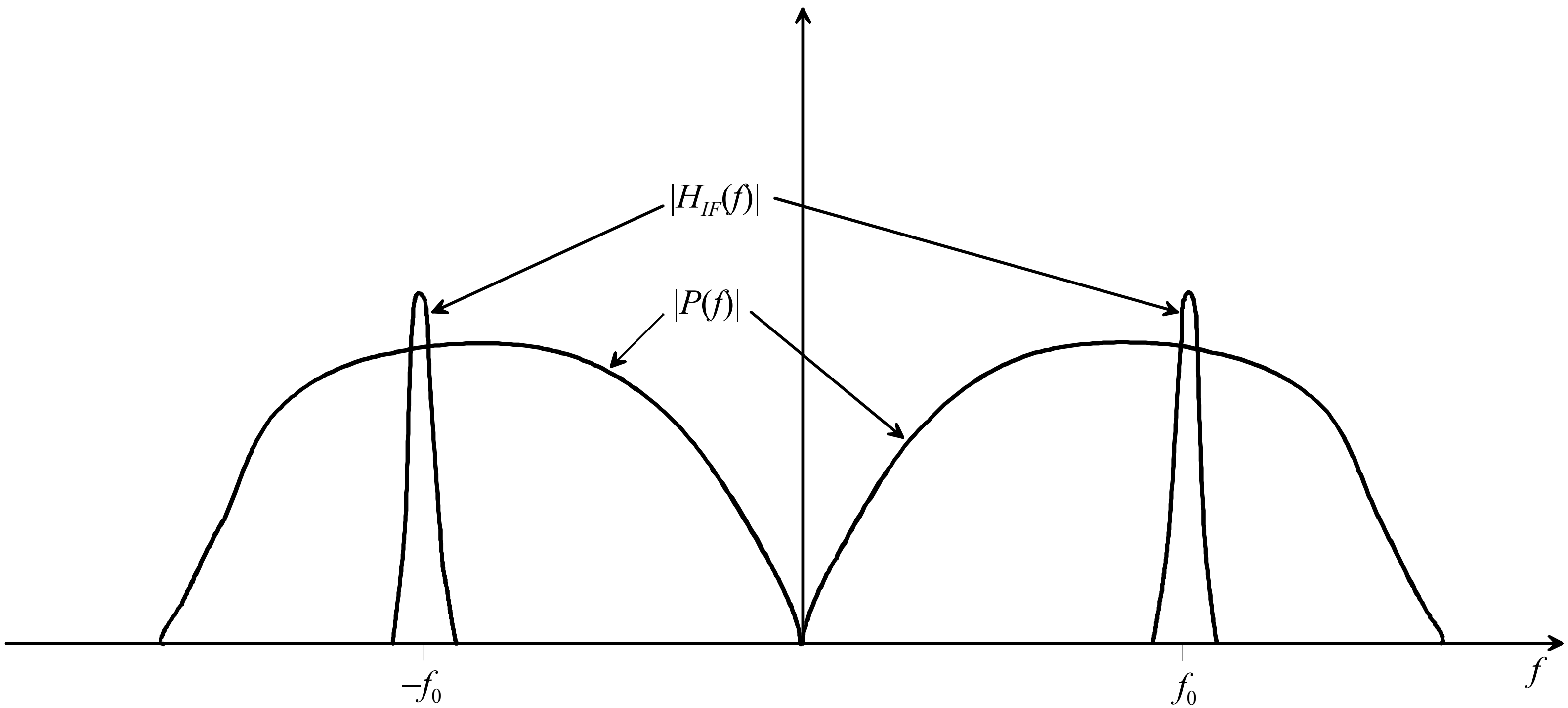
General Narrowband Receiver Model

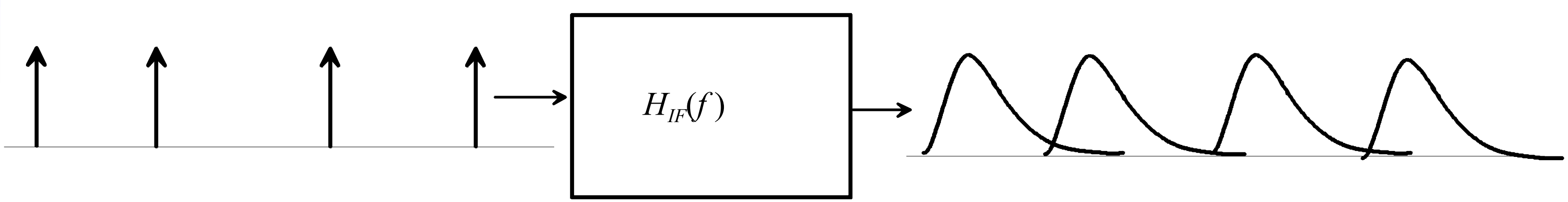


Equivalent bandpass filter characteristic

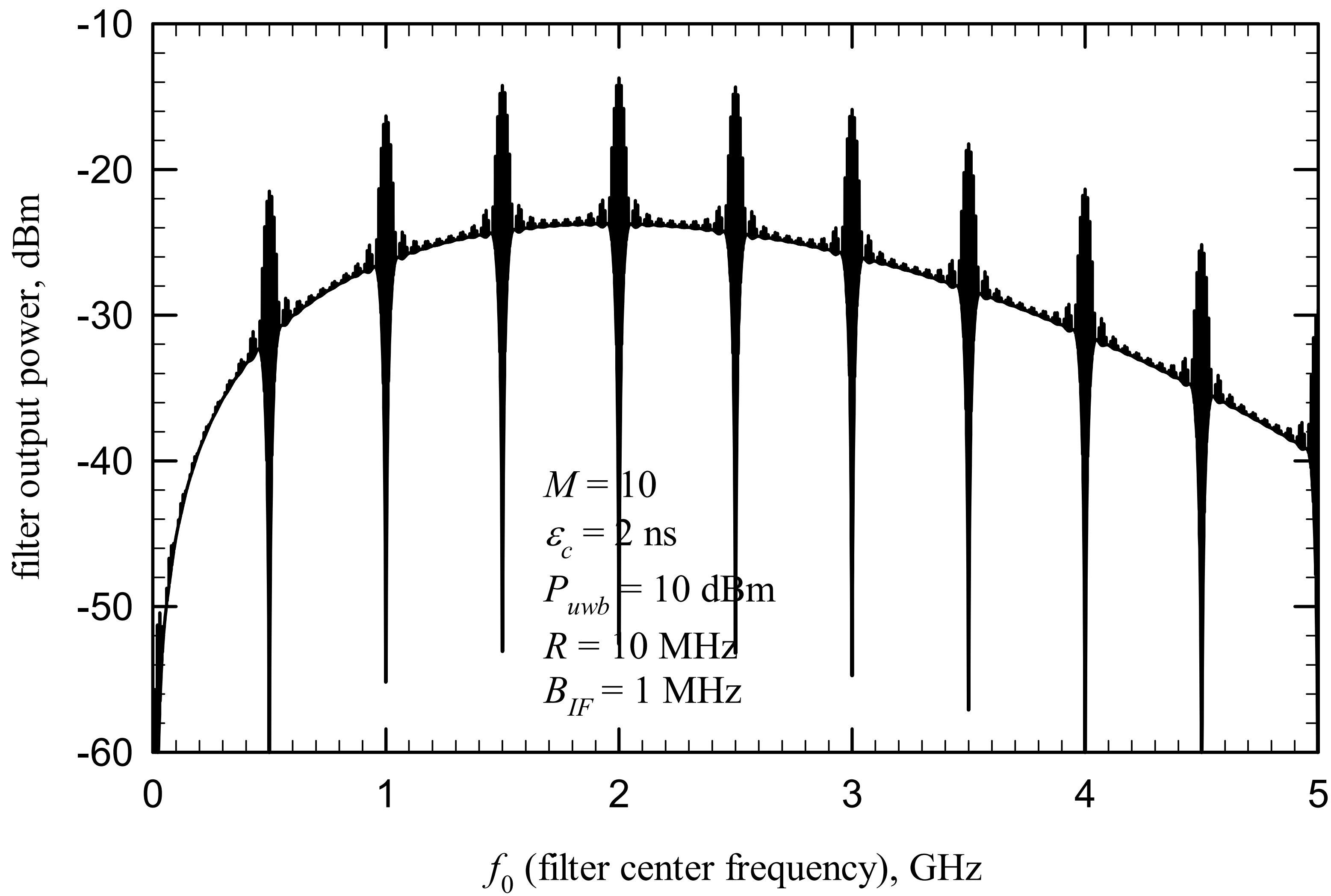


Spectral (PSD Analysis) and Temporal (Simulation) Views of Problem

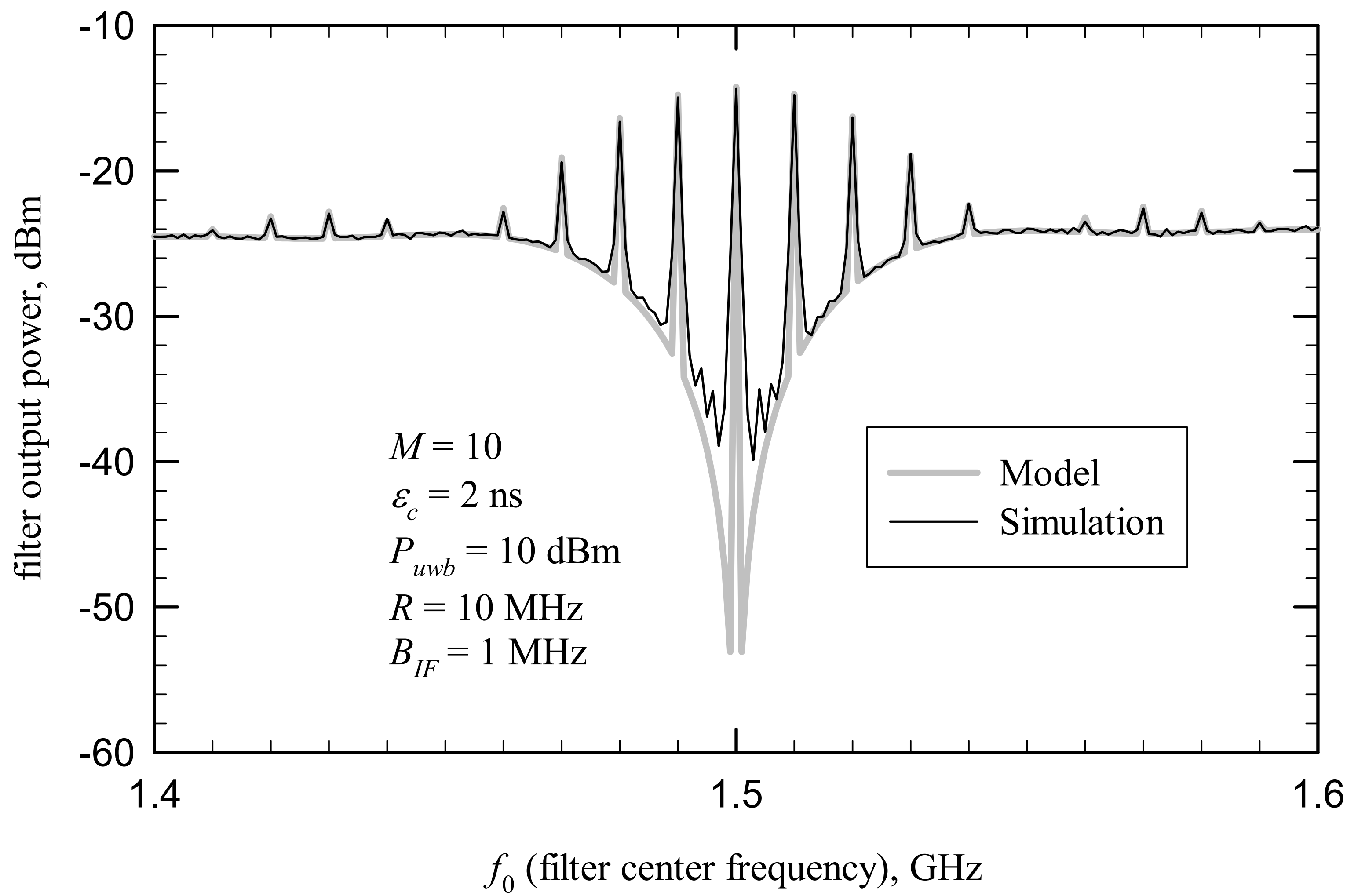




PSD Example: Partial-Frame 2-ns Dithering

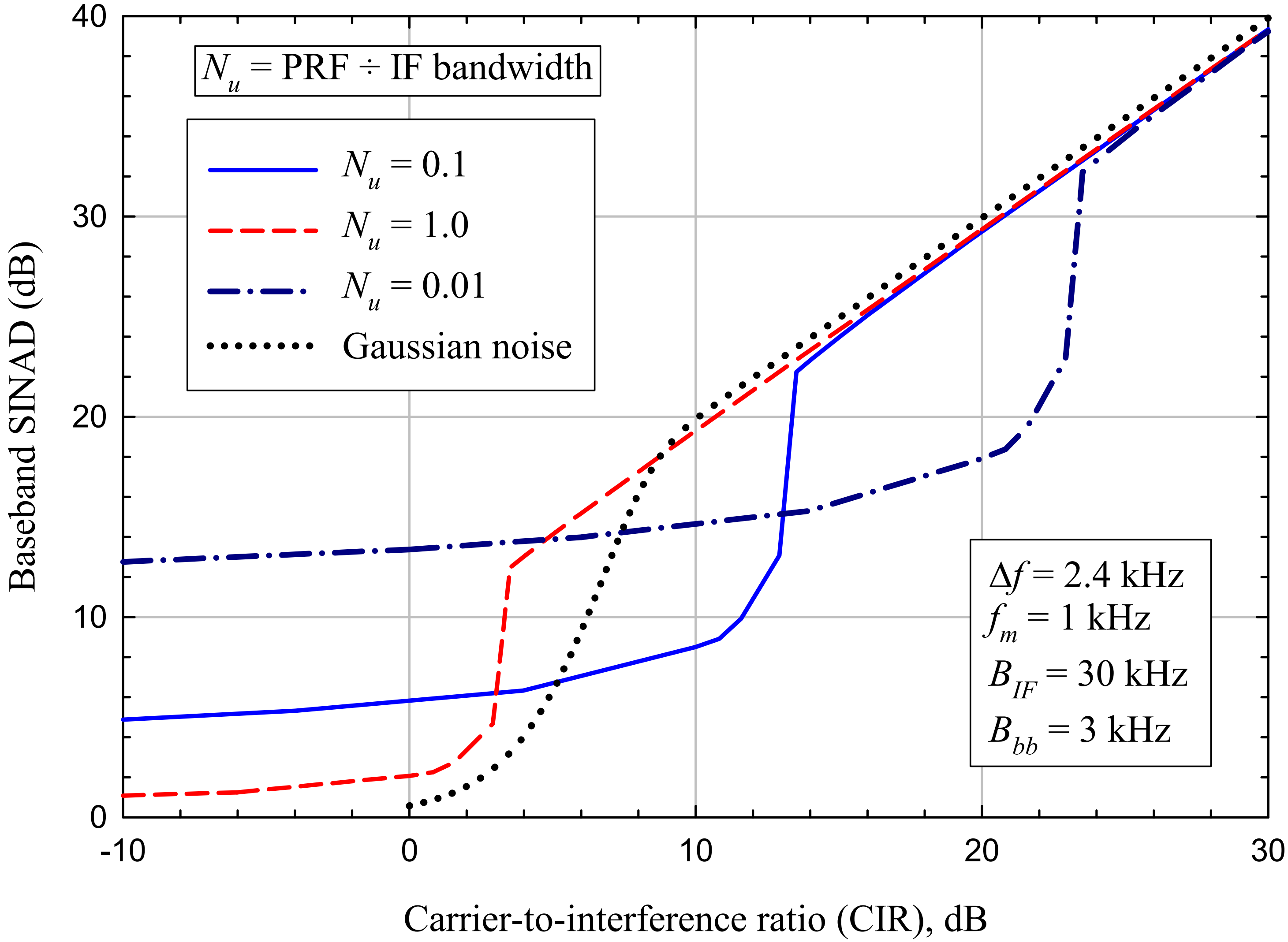


Closeup – with Simulation Results

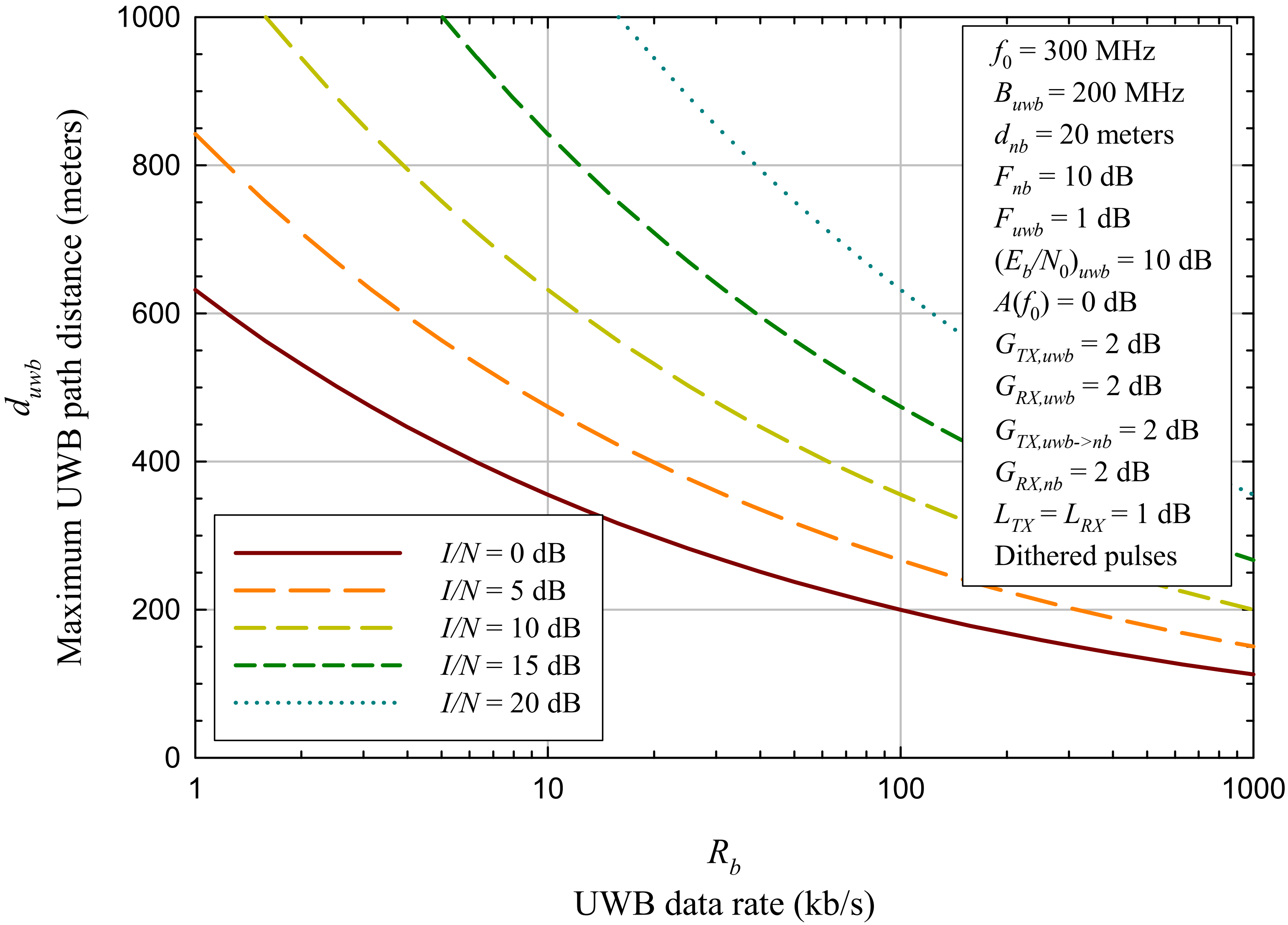


Telcordia Technologies
Performance from Experience

Modeling the Test Procedure for an VHF/UHF Receiver in the FM Mode

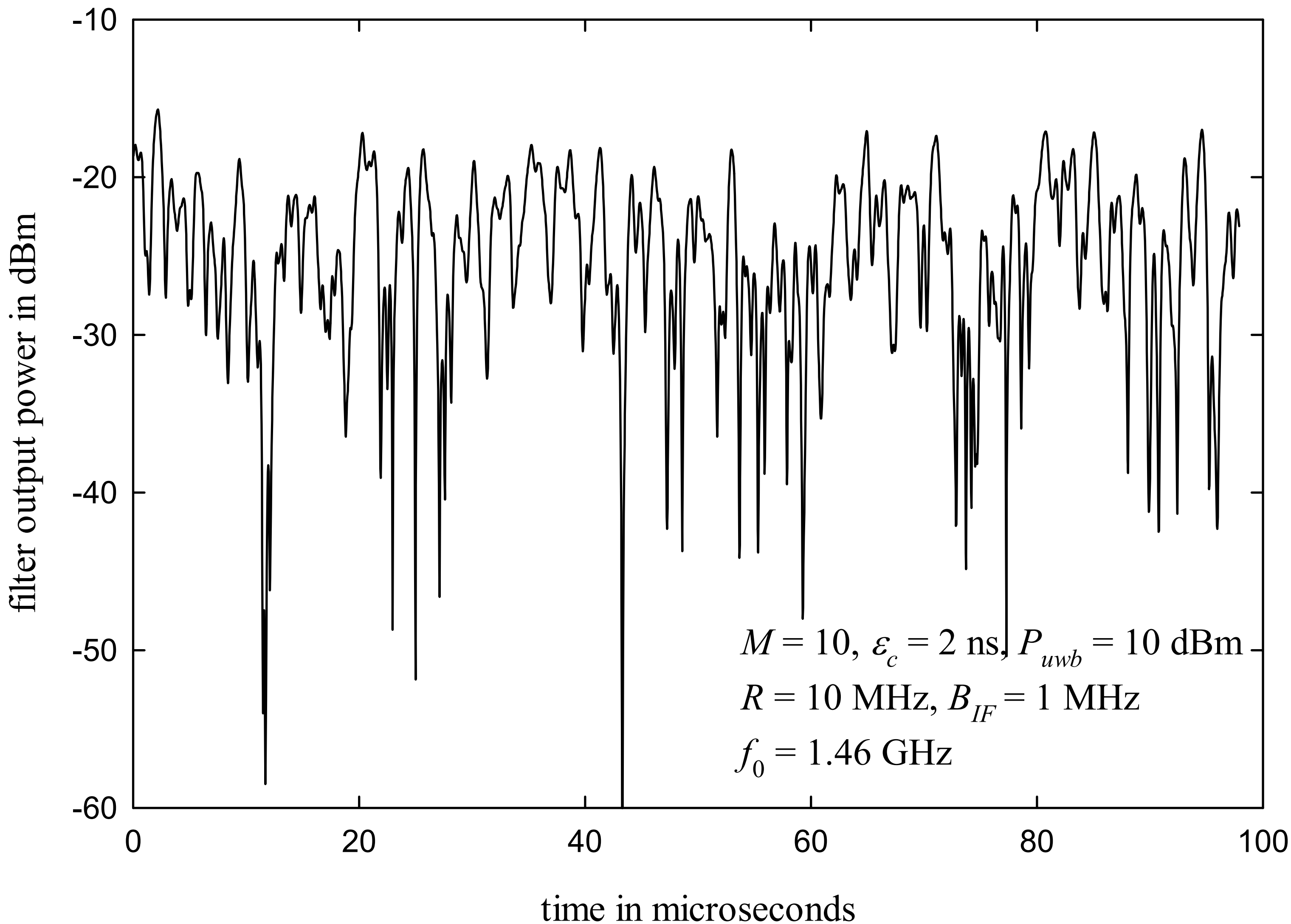


UWB/Legacy NB Coexistence Example



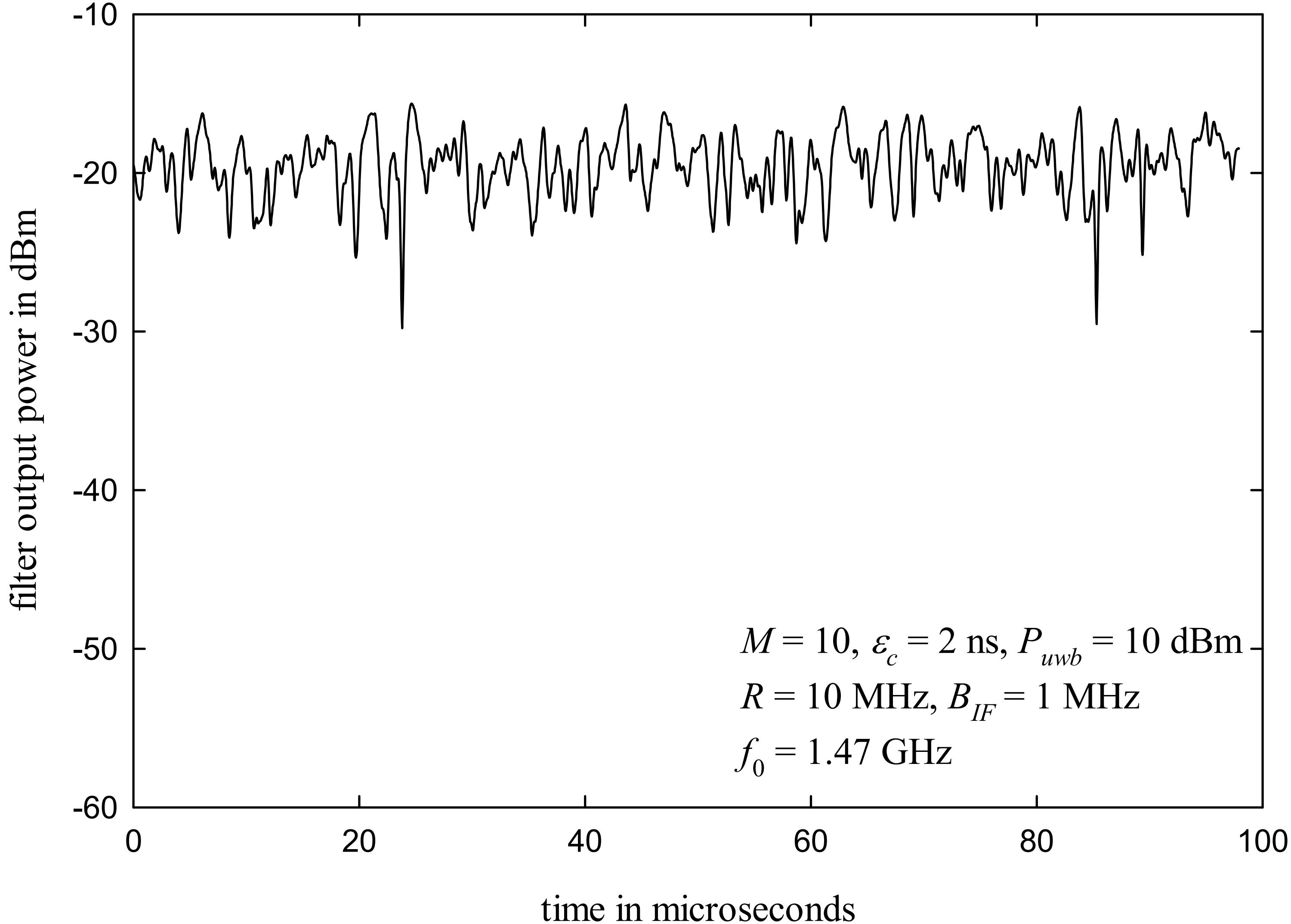
BACKUP SLIDES

Simulation – Zero Span – 1.46 GHz

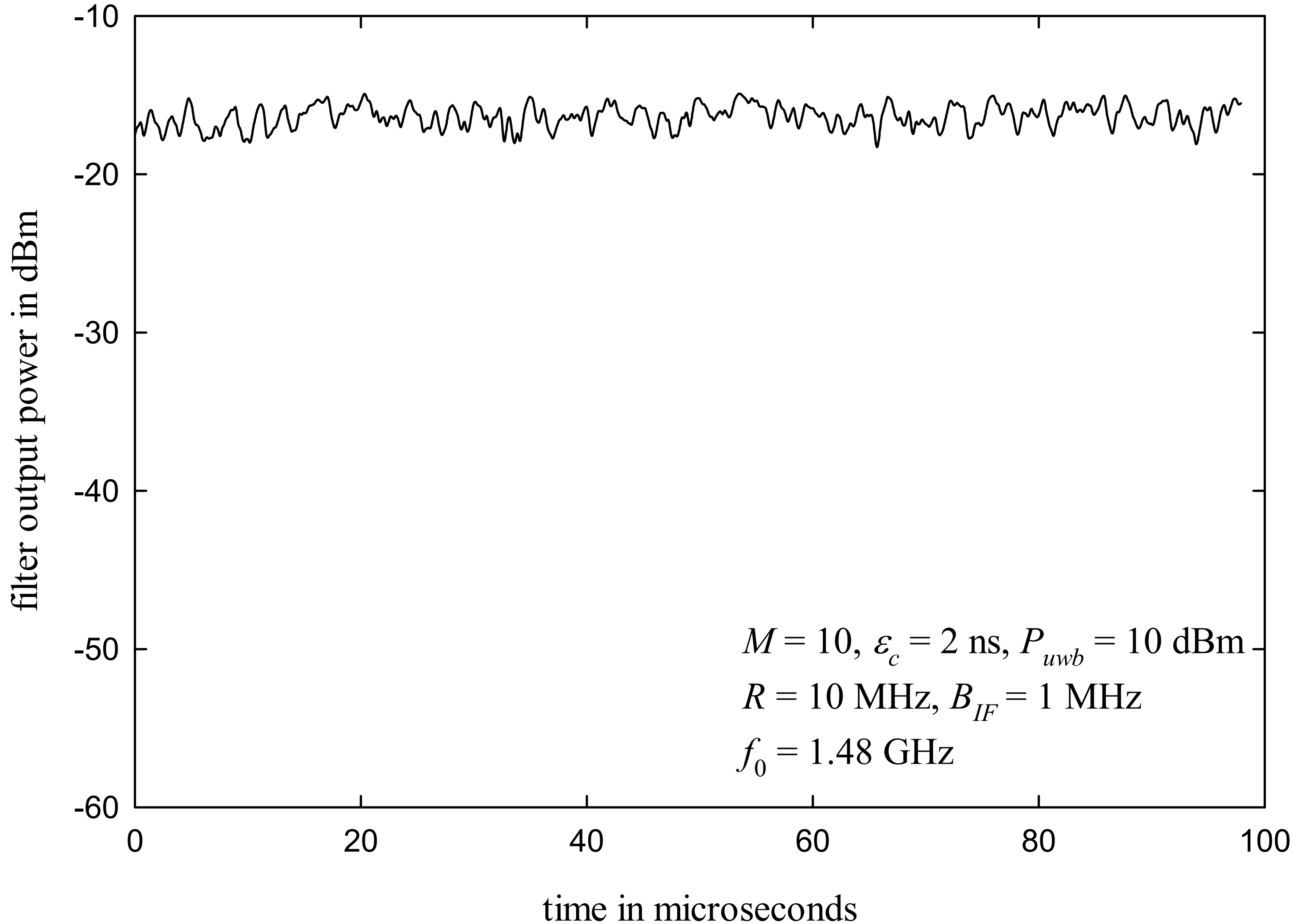


Telcordia Technologies
Performance from Experience
DARPA
ATO Advanced Technology Office

Simulation – Zero Span – 1.47 GHz



Simulation – Zero Span – 1.48 GHz

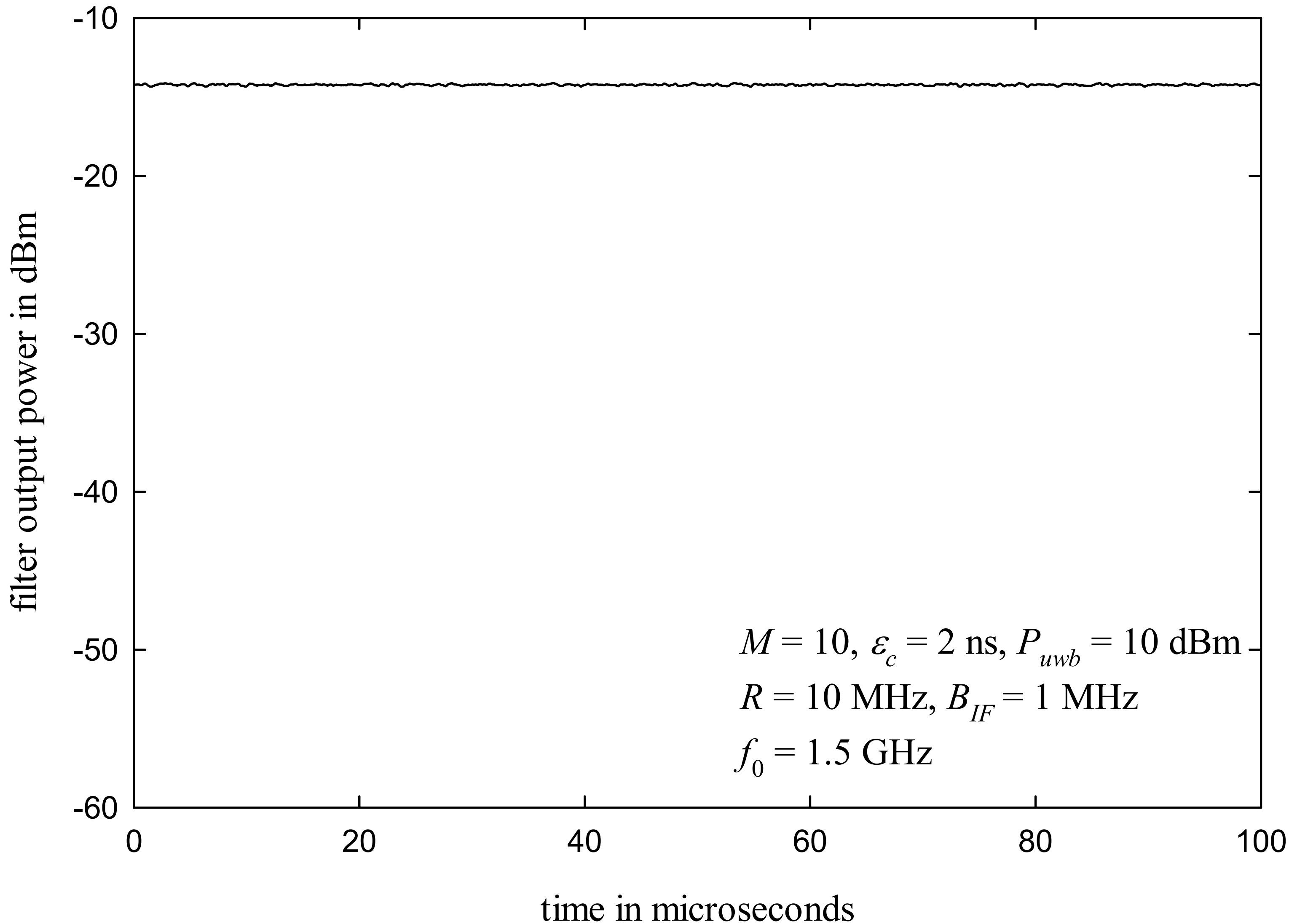


Telcordia Technologies
Performance from Experience

DARPA

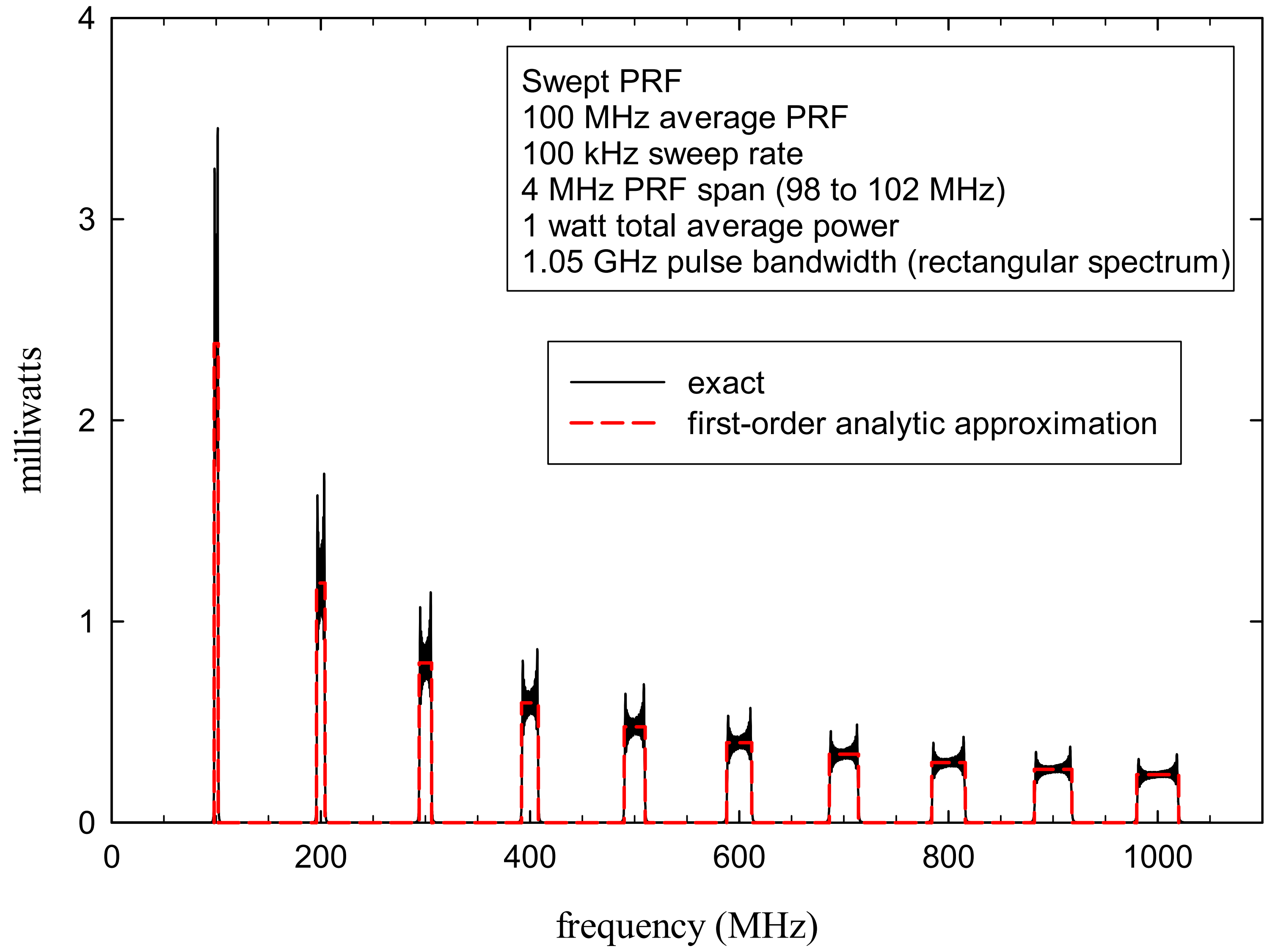
Advanced Technology Office

Simulation – Zero Span – 1.5 GHz

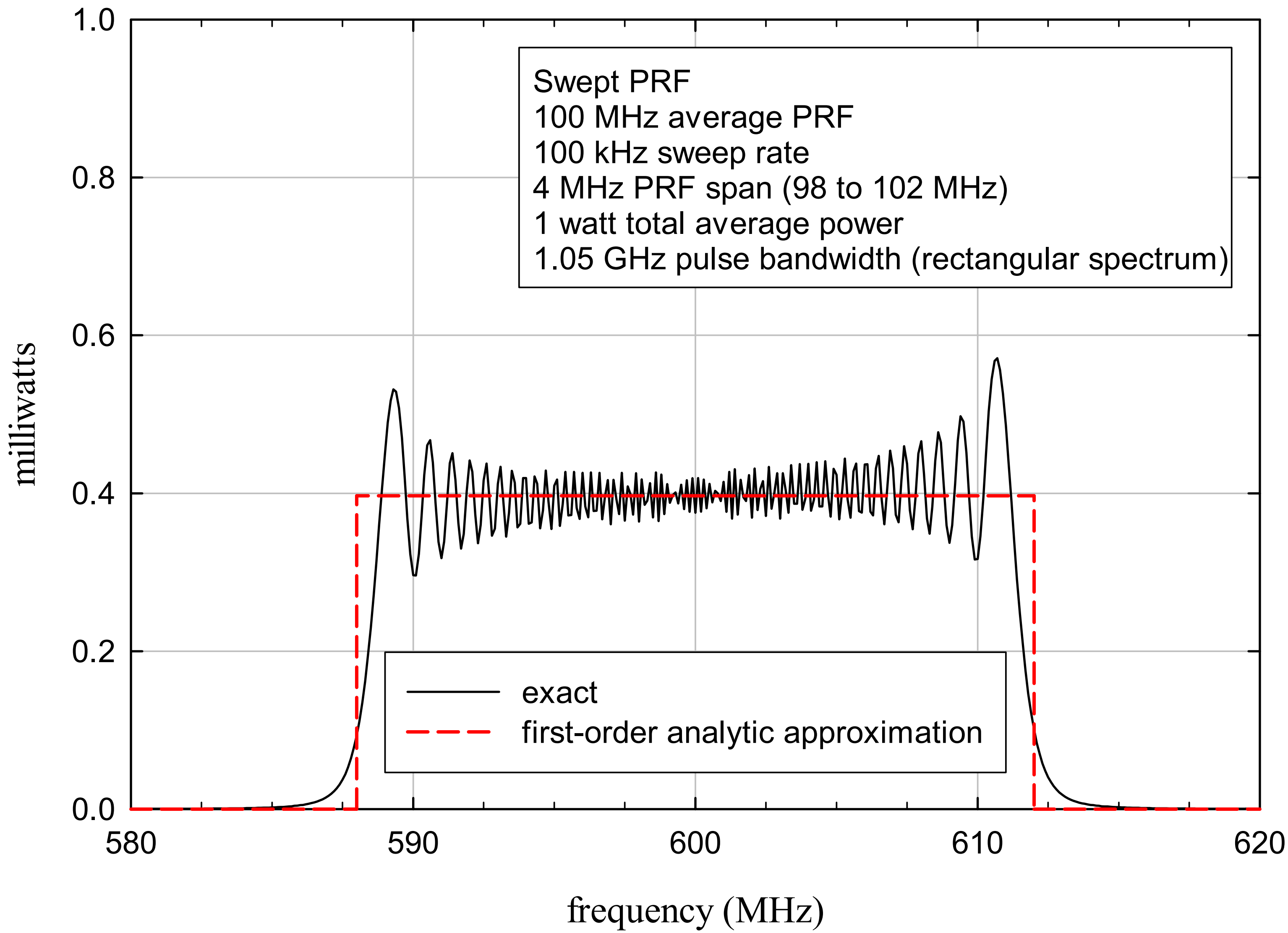


Telcordia Technologies
Performance from Experience

PRF Modulation Example: Swept PRF



Closeup of Swept PRF Spectrum



Telcordia Technologies
Performance from Experience

DARPA

UWB Effects on Receiver Performance

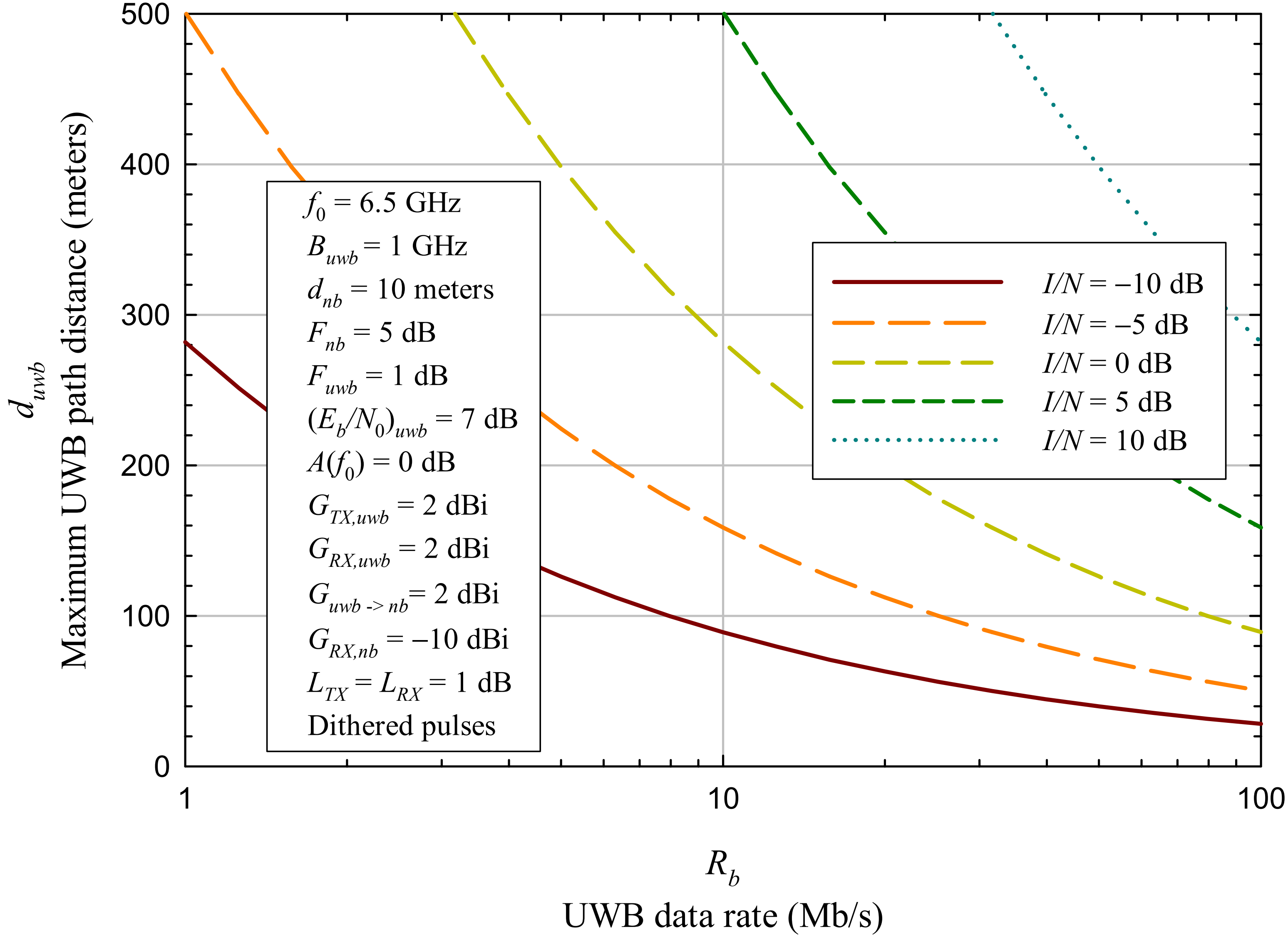
- N_u is the ratio of the pulse rate to the NB victim IF bandwidth
- There are 3 primary interference cases:
  - $N_u \leq 1$, which gives pulsed interference to the detector.
  - $N_u > 1$ with constant pulse rate, which can give a tone within the passband.
  - $N_u > 1$ with dithering or modulation, which can give a noise-like signal, plus in some cases a CW component.
- The first two cases were explored for three types of fixed-frequency digital communications receivers and for an analog FM receiver. The third case, in the limit, gives results similar to those of Gaussian noise, which are well-known.
- The primary factor determining receiver impact seems to be average UWB interference power within receiver passband (i.e., within the final IF bandwidth).
- Impact also depends on nature of the interference: pulsed (pulse rate less than signal bandwidth); tone-like, or noise-like.

UWB/Legacy System Coexistence Calculations

Assumptions and Limitations

- Based on average UWB interference in legacy system passband
- Aggregate interference effects have been ignored.
- NB receiver center has been assumed to be at maximum of UWB pulse energy spectrum (worst-case assumption).
- Interference to the UWB receiver has been ignored.
- A smart UWB system could be envisioned that senses the NB system and places nulls in the spectrum.
- The gain of a directional UWB antenna, as seen by a narrowband system, needs to be better understood.
- Narrowband path models have been used to compute the path loss for the UWB system.

High Data Rate UWB Comm System



Telcordia Technologies
Performance from Experience

UWB Range/Rate Equations

$$\underbrace{L_{p,uwb} + 10\log\left(\frac{R}{B_{uwb}}\right)}_{\text{UWB rate/range performance}} = \underbrace{\left(\frac{I}{N}\right)_{\text{dB}} + L_{p,nb}}_{\text{Legacy system protection criterion}} + F_{nb} - A(f_0) - \underbrace{(X + F_{uwb})}_{\text{UWB receiver sensitivity}}$$

$$+ \underbrace{G_{TX,uwb} + G_{RX,uwb} - G_{TX,uwb \to nb} - G_{RX,nb}}_{\text{net effect of antenna gains and system losses}}$$

$$R = \begin{cases} R_b \text{ (bit rate) for communications} \\ R_p \text{ (pulse rate) for radar} \end{cases} \qquad X = \begin{cases} 10\log(E_b / N_0) \text{ communications} \\ 10\log(E_p / N_0) \text{ radar} \end{cases}$$

$L_{p,uwb}$ = path loss from UWB transmitter to UWB receiver

(two - way path loss with reflection from target for radar)

L_{nb} = path loss from UWB transmitter to legacy receiver

Telcordia Technologies

Performance from Experience

Parameter Definitions

f_0	UWB and legacy system center frequency (MHz)
B_{uwb}	UWB bandwidth (MHz)
d_{nb}	distance from UWB transmitter to legacy receiver (meters)
F_{nb}	legacy receiver noise figure (dB)
F_{uwb}	UWB receiver noise figure (dB)
E_b	energy per received UWB data bit (joules)
R_b	UWB bit rate
E_p	energy per received UWB pulse (joules)
R_p	UWB pulse rate
N_0	thermal noise power spectral density (watts/Hz)
$A(f_0)$	UWB spectral rolloff at legacy center frequency
$G_{TX,uwb}$	UWB transmit antenna gain
$G_{RX,uwb}$	UWB receive antenna gain
$G_{TX,uwb \rightarrow nb}$	UWB transmit antenna gain as seen by legacy receiver
$G_{RX,nb}$	legacy receiver antenna gain
L_{TX}, L_{RX}	transmit and receive chain losses
I/N	ratio of UWB interference to thermal noise power at legacy IF

Interference to UWB from Legacy Systems

$$\frac{E_b}{N_0} = \underbrace{\left(B_{uwb}/R_b\right)}_{\text{Spreading Gain}} \cdot \frac{\bar{S}}{J+N+I} \cong \frac{S_{peak}}{J+N+I}$$

The final equality assumes 1 bit per pulse

$$\frac{E_b}{N_0} \geq 0\text{ dB (10 dB is reasonable as an example)}$$

With thermal noise only and a 1-dB noise figure, N_0 = –173 dBm/MHz. If E_b = –163 dBm/Hz and R_b = 10 kb/s then the average received power must be:

$$\bar{S} = -163 + 10\log 10\times10^3 = -123\text{ dBm}$$

$$\text{With } B_{uwb} = 200\text{ MHz and } R_b = 10\text{ kb/s}$$

$$S_{peak} = -80\text{ dBm, so } S_{peak}/I = -74\text{ dBm}$$

The narrowband interference must effectively be removed from the UWB passband