Tokyo Tech.

Experimental Evaluation Scheme of UWB Antenna Performance

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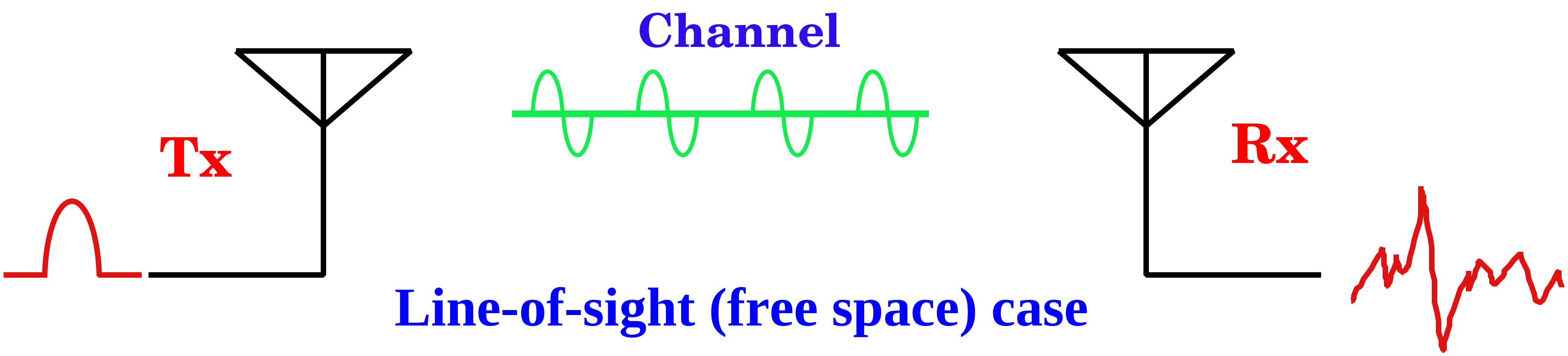
16 June 2003

Outline

- Background
- Extension of Friis' Transmission Formula for UWB Systems
- Preparation for the Experiments
- Results of Experiments
- Conclusion and Future Works

Background

Link budget estimation of ultra-wideband (UWB) transmission



Line-of-sight (free space) case

Attenuation
+
Distortion
} **of signal**

Effect of distortion is not considered in Friis' formula because the formula is expressed in terms of amplitude .

We propose a method

Extension of Friis' transmission formula for UWB signal

↓

Experimental evaluation scheme of UWB antenna performance is based on extended Friis' transmission formula

↓

effects of distortion due to frequency characteristics of antennas

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Introduction of matched filter in the receiver to get maximum signal-to-noise ratio (SNR) output

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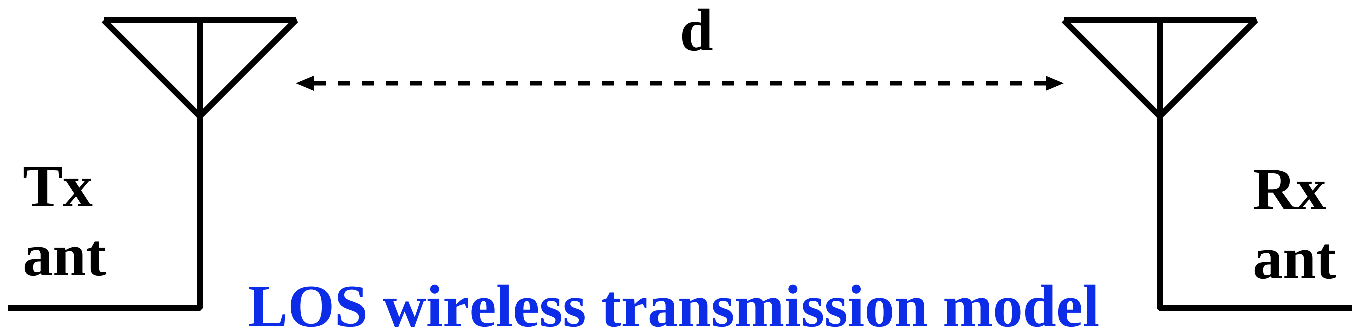
Definition of power gain used for link budget

Extension of Friis' Transmission Formula for UWB Systems - 1

Friis' Transmission Formula



LOS wireless transmission model

Transmission gain

$$G_{Friis}(f) = \frac{P_r(f)}{P_t(f)} = G_f(f)G_r(f)G_t(f)$$

Free space propagation gain

$$G_f(f) = \left(\frac{\lambda}{4\pi d}\right)^2$$

where

f : **frequency**

$G_t(f)$: **absolute gain of Tx ant.**

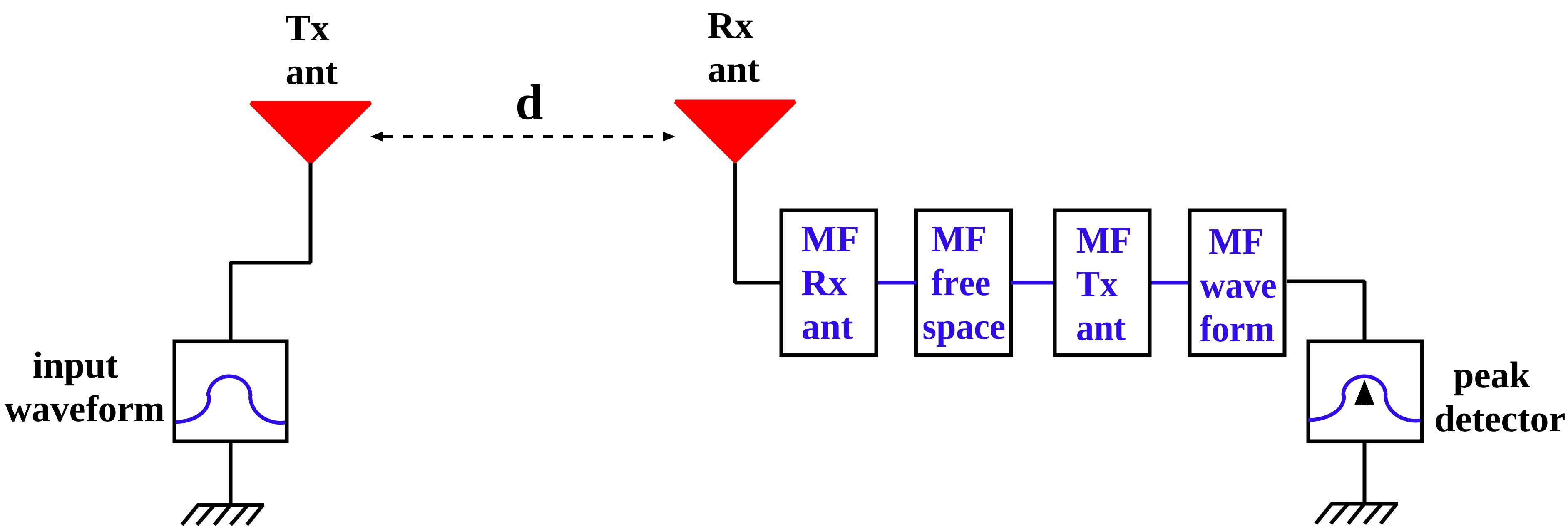
$G_r(f)$: **absolute gain of Rx ant.**

→ **roots of distortion**

λ : **wavelength**

Extension of Friis' Transmission Formula for UWB Systems - 2

Extension of Friis' Transmission Formula for Wideband waveform transmission



Block diagram of transmission System for Extension of Friis' Transmission Formula to treat UWB signal.

Extension of Friis' Transmission Formula for UWB Systems - 3

Input signal

$$v_t(t) = E_t \delta(t) * h_t(t)$$

The corresponding transfer function

$$H_{e-Friis}(f) = \frac{V_r(f)}{E_t} = H_f H_t \vec{\boldsymbol{H}}_r \cdot \vec{\boldsymbol{H}}_t$$

where

$$\vec{\boldsymbol{H}}_a = \vec{\boldsymbol{H}}_a(\theta_a,\ \varphi_a,\ f)$$ **: polarization transfer function (V and H pols.)**

$$a = \mathrm{r}\ or\ \mathrm{t}$$

Extension of Friis' Transmission Formula for UWB Systems - 4

complex transfer function of free space

$$H_f = \frac{\lambda}{4\pi d}\exp(-\jmath kd) \quad , \qquad k = \frac{2\pi}{\lambda}$$

the unit vectors of Tx and Rx antennas.

$$\hat{\theta}_r = \hat{\theta}_t \quad , \quad \hat{\varphi}_r = -\hat{\varphi}_t$$

matched filter normalized to satisfy constant noise power output.

$$H_{MF}(f) = \frac{H^*_{e-Friis}(f)}{\sqrt{\int_{-\infty}^{\infty} \left|H_{e-Friis}(f)\right|^2 df}}$$

Extension of Friis' Transmission Formula for UWB Systems - 5

The output waveform from matched filter

$$v_{MF}(t) = h_{e-Friis}(t) * h_{MF}(t) = \frac{h_{e-Friis}(t) * h_{e-Friis}(-t)}{\sqrt{\int_{-\infty}^{\infty} h_{e-Friis}^2(t)dt}}$$

Maximum

$$\max_t v_{MF}(t) = v_{MF}(0) = \int_{-\infty}^{\infty} V_{MF}(f)df$$

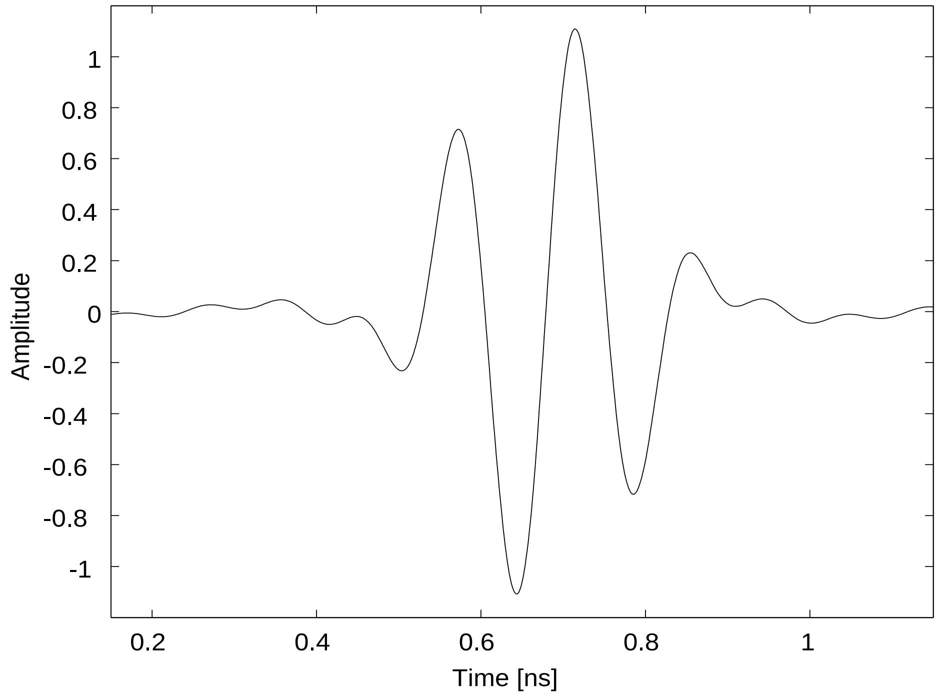
$$= \sqrt{\int_{-\infty}^{\infty} \left| H_{e-Friis}(f) \right|^2 df}$$

This equation includes the frequency response of the antenna, the propagation loss, and the spectrum of the transmission signal.

Preparation for the Experiments - 1

UWB Signal Model

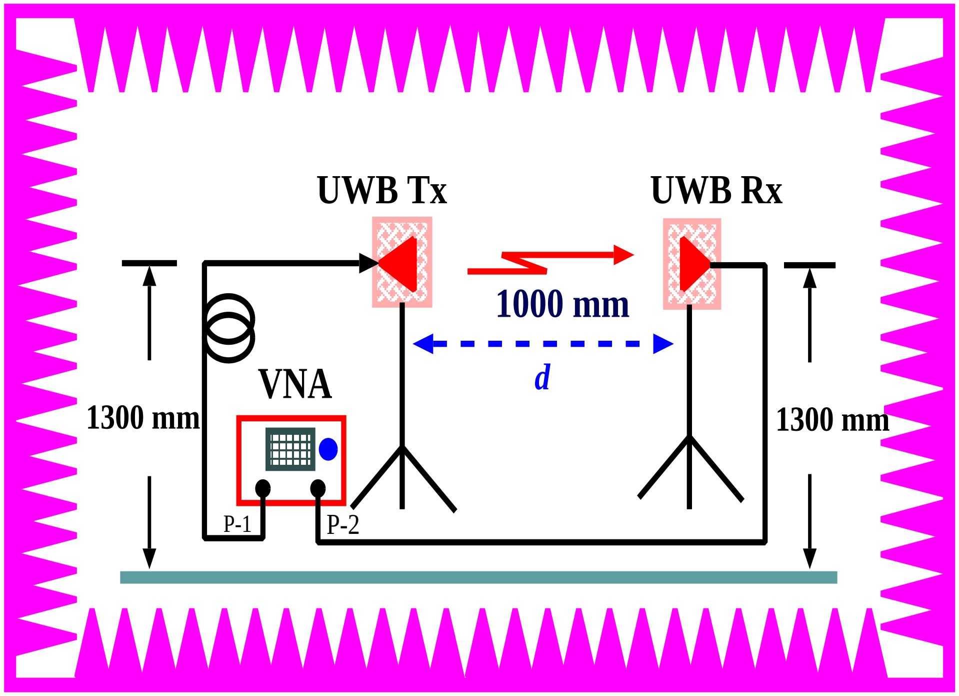
- **Frequency band from 3.1 GHz to 10.6 GHz**

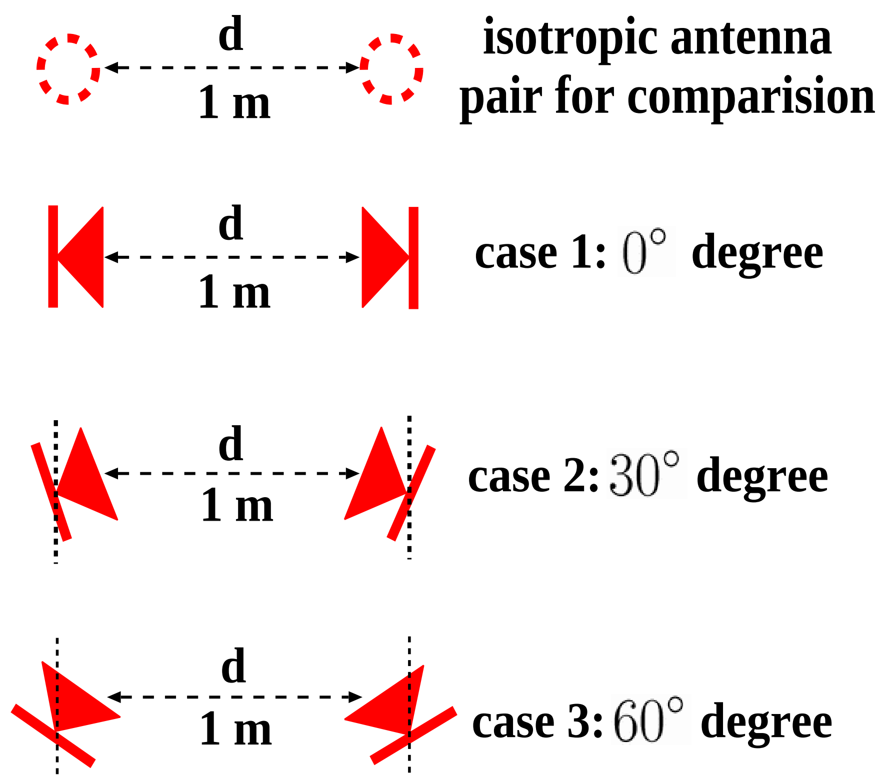


The transmission waveform of UWB signal

Preparation for the Experiments - 2

Instruments Setup



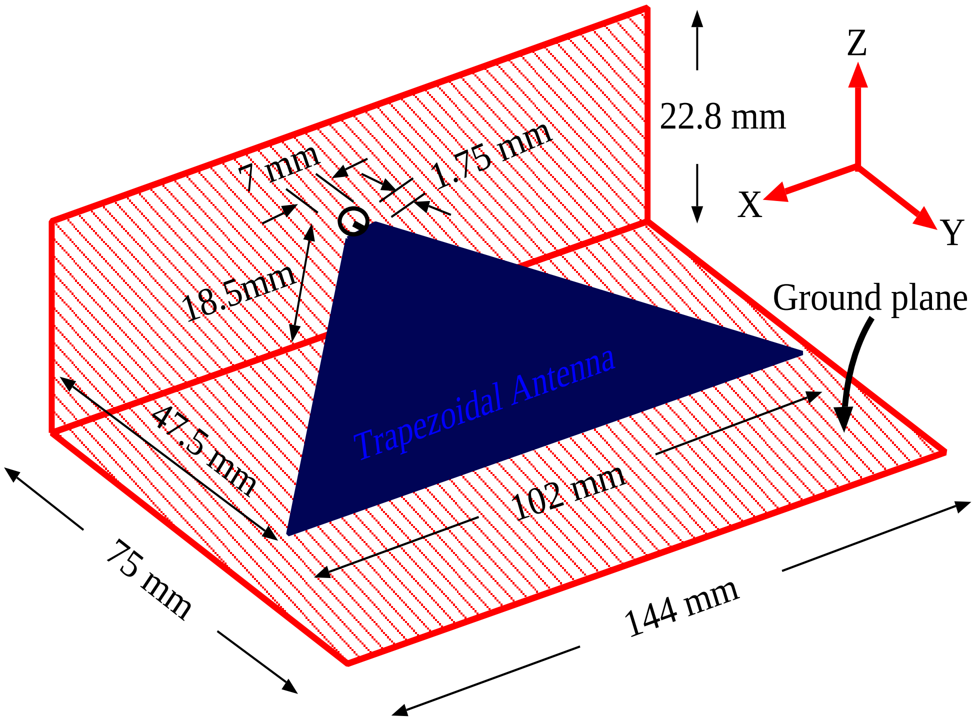


The instruments setup

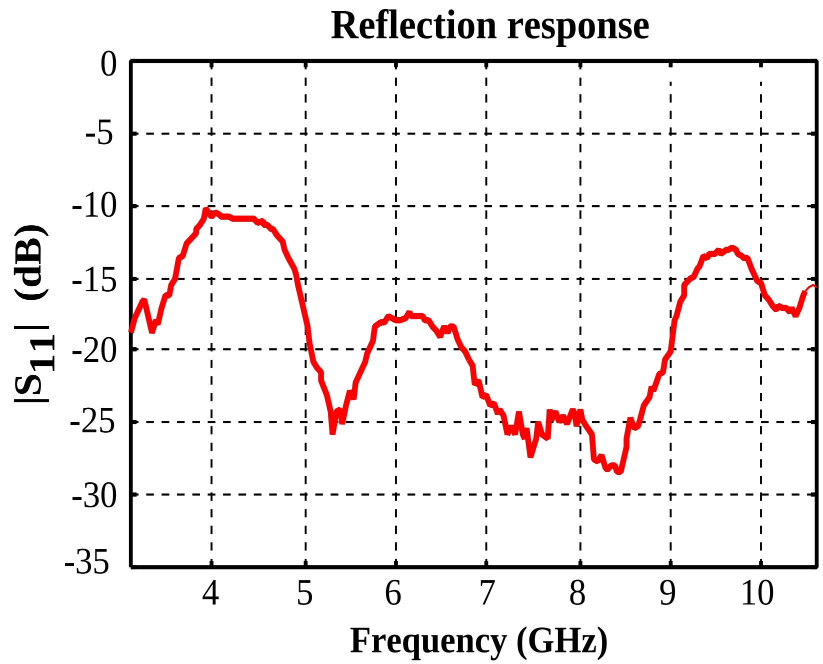
Orientation of two trapezoidal antenna

Preparation for the Experiments - 3

Antenna Under Test



Structure and dimension of trapezoidal antenna



$|S_{11}|$ Characterstics of trapezoidal antenna

Preparation for the Experiments - 4

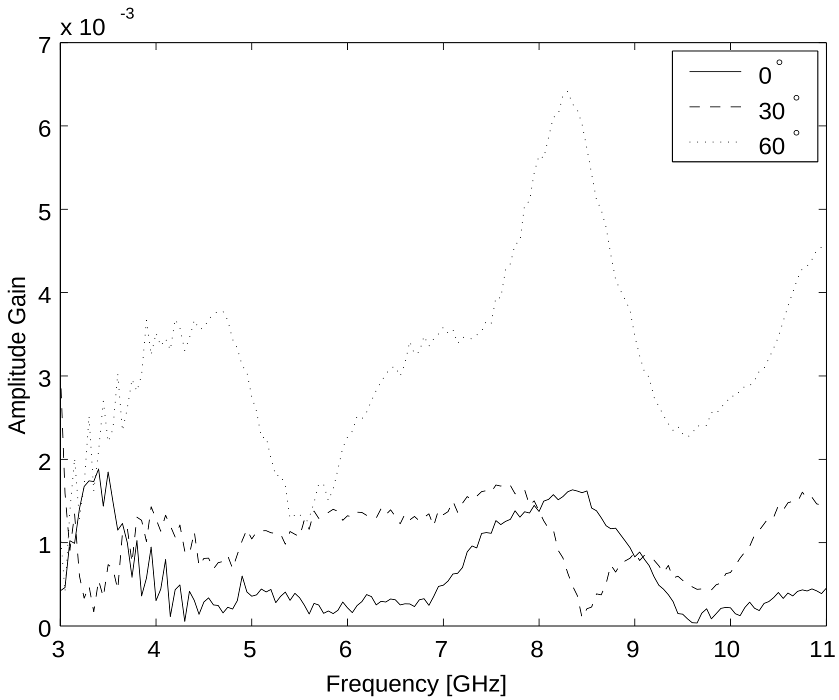
Parameters of Experiments

Table 1:

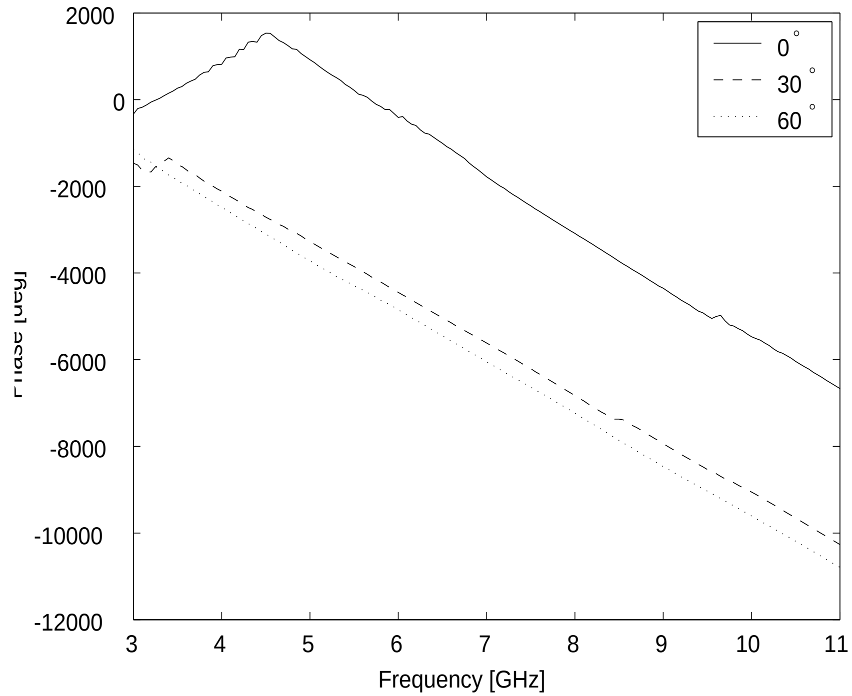
Parameter	Value
Frequency range	2 GHz to 12 GHz
Number of frequency point	1601
Dynamic power range	80 dB
IF bandwidth	300 MHz
Tx antenna height	1.3 m
Rx antenna height	1.3 m
Distance between Tx and Rx	1.0 m
Pointing angle	0 / 30 / 60 degrees

Results of Experiments - 1

Measured transfer functions for different antenna pointing condition: ***amplitude***

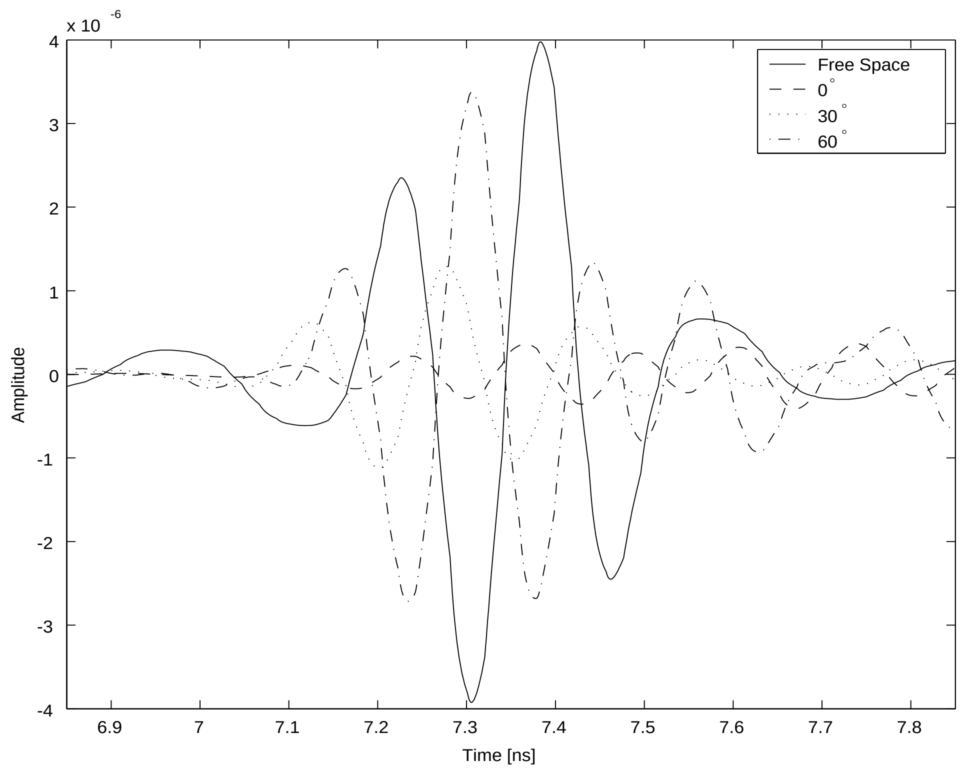


Measured transfer functions for different antenna pointing condition: ***phase***



Results of Experiments - 2

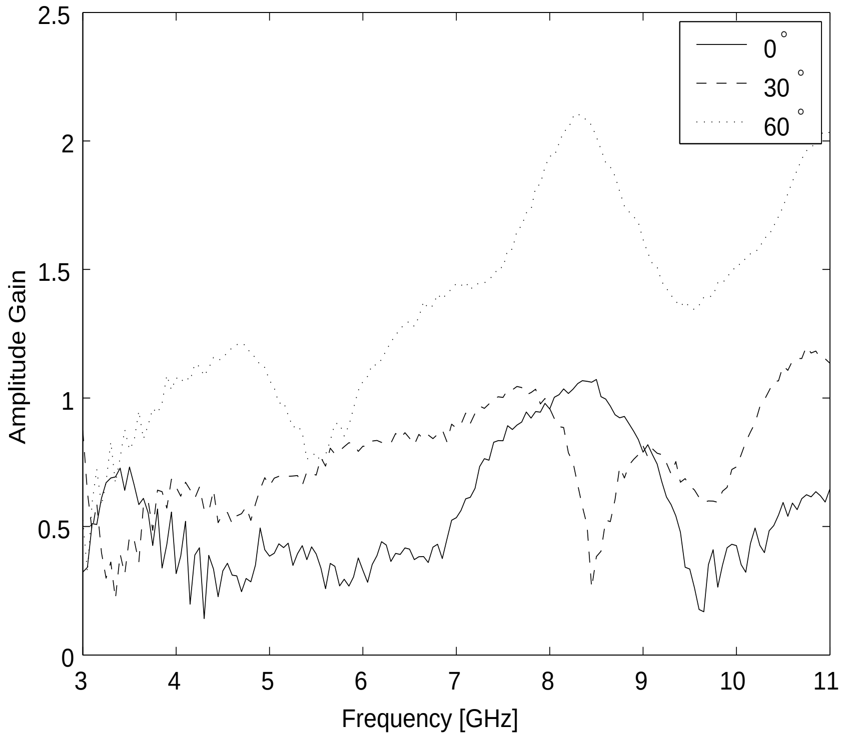
Received waveform
at the antenna output



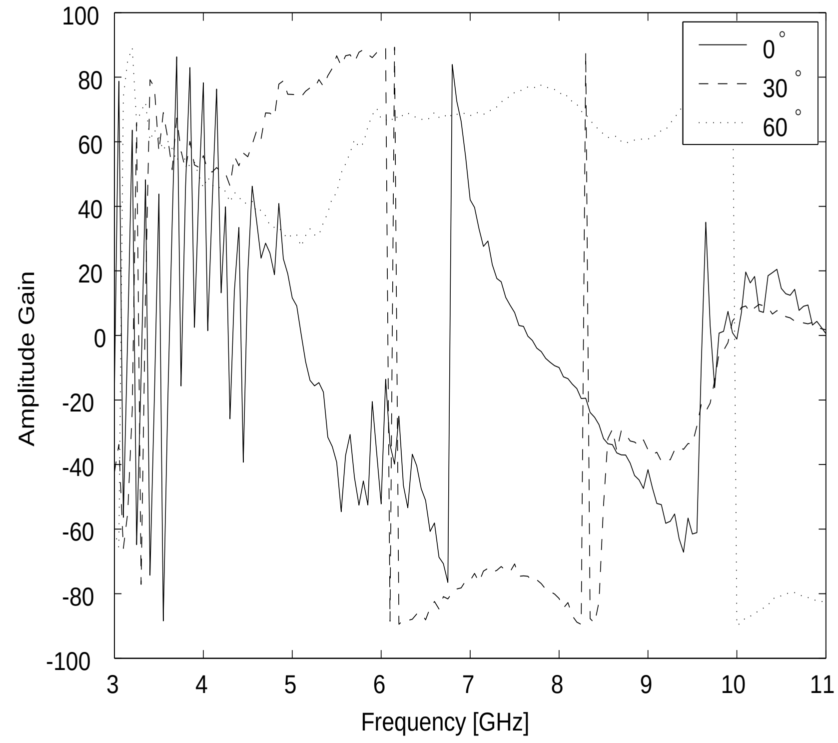
very much distorted
and length become longer.

Results of Experiments - 3

Antenna transfer function: *amplitude*

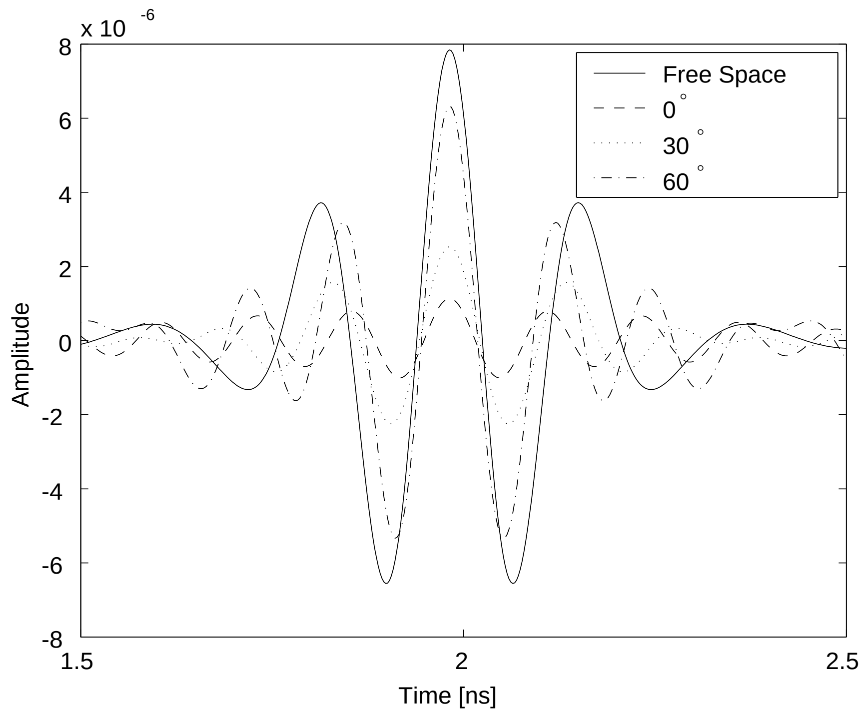


Antenna transfer function: *phase*

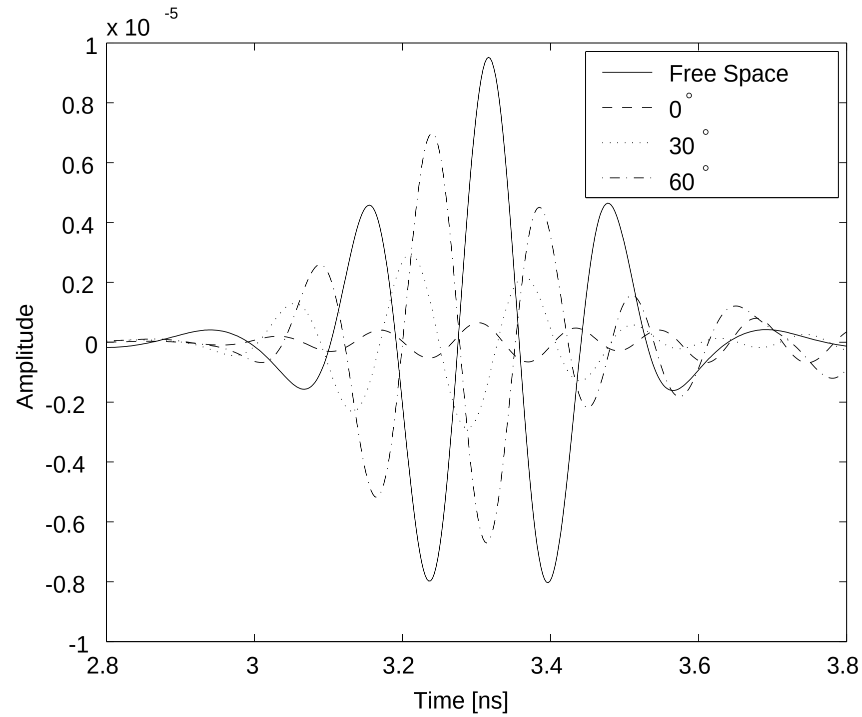


Results of Experiments - 4

Output of matched filter:
optimal



Output of the matched filter:
free space approximation



Results of Experiments - 5

***Table 2:** Compare with relative gain of (antenna + matched filter), with respect to ideal isotropic antenna*

Filter	Gain [dBi]		
	0°	30°	60°
Optimum	-16.8	-9.8	-1.9
Isotropic approximation	-22.8	-10.6	-3.3

***Table 3:** Correlation coefficient between the impulse responses of the received signal and the approximate matched filter by using isotropic antenna.*

Orientation	0°	30°	60°
Correlation	0.46	0.86	0.85

Conclusion and Future works

Developed an experimental scheme for UWB antenna performance using the extended Friis' transmission formula and matched filter to get the maximum SNR.

This demonstrated scheme can be used for UWB antenna performance and indoor/outdoor propagation and modeling in UWB systems.

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Fading and Shadowing model

Frequency characteristics

> Antenna
> Human body effect
> Indoor multipath effect

Thank you for attention