Antenna & Propagation

Radio channels models in ADS

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Path loss in ADS

- LFS = pathloss in free-space environment, in dB
- LRA = pathloss in rural area environment, in dB
- LHT = pathloss in hilly terrain environment, in dB
- LTU = pathloss in typical urban environment, in dB
- LTS = pathloss in typical suburban environment, in dB
- fc = propagation (carrier) frequency, in MHz
- λc = wavelength associated with propagation (carrier) frequency
- D = major antenna dimension
- HBS = base station antenna height, in meters
- HMS = mobile station antenna height, in meters
- R = distance between transmit and receive antenna, in km

Free space

- Free-space pathloss option provides the designer with an optimistic model. This
- option is given (in dB) by
- LFS = + 20log10fc + 20log10R + 32.4
- There are a wide variety of pathloss models—the most widely used is Hata’s. Hata’s
- pathloss model [6] is based on an extensive data base derived by Okumura [7] from
- measurements in and around Tokyo. Hata’s pathloss models cover urban, rural, and
- suburban environments and include the transmit and receive antenna heights.

Hata model

- The *typical urban Hata model is given by*
- LTU = 69.55 + 26.16log10fc − 13.82log10HBS − a (HMS)
- + (44.9 − 6.55log10HBS)log10R
- The correction factor for small- to medium-size cities is given by
- a = (1.1log10 fc − 0.7)HMS − (1.56 log10 fc − 0.8)
- Hata's urban model is equivalent to Type=TU in propagation components.
- The *typical suburban Hata model is given in terms of LTU with a correction factor:*
- LTS = LTU − 2[log10(fc/28)]2 − 5.4
- Similarly, the *rural Hata model is a corrected form of LTU as*
- LRA = LTU − 4.78(log10fc)2 + 18.33log10fc − 40.94
- Hata's rural model is equivalent to Type = RA in propagation components.

Multipath and fading – ADS parameters

- Definitions:
- V = vehicle speed, in m/s
- Fc = propagation (carrier) frequency, in Hz
- ωc = propagation (carrier) frequency, in radian/sec
- ν = Doppler frequency, in Hz
- νm = maximum Doppler frequency, in Hz
- S(t) = transmitted (RF) signal
- s(t) = complex envelope of transmitted signal
- R(t) = received (RF) signal
- r(t) = complex envelope of received signal
- αn= random amplitude of *nth signal echo*
- γn = phase retardation of *nth signal echo*
- τn = time-delay of *nth signal echo*
- Gt(θ, ϕ) = directive gain of transmitting antenna as a function of elevation and
- azimuth angles
- Gr(θ, ϕ) = directive gain of receiving antenna as a function of elevation and
- azimuth angles

Fundamentals

- Radio waves are received not only via direct path but often by scattering off numerous objects. Delay, attenuation and carrier phase shift are some of the alterations the transmitted signal experiences. This process can be modeled as a linear filter with randomly time-varying impulse response.
- In a multipath environment, a transmitted RF signal is:

$$S(t) = Real\left\{s(t)e^{j2\pi f_c t}\right\}$$

Is received in the form:

$$R(t) = Real\left\{\sum_n \sqrt{G_t(\theta_n, \psi_n)G_r(\theta_n, \psi_n)}\,\alpha_n(t)s(t-\tau_n)e^{j[2\pi f_c(t-\tau_n)-\gamma_n]}\right\}$$

Rayleigh distribution

$$r(t) = \sum_n \sqrt{G_t(\theta_n, \psi_n) G_r(\theta_n, \psi_n)}\, \alpha_n(t) s(t - \tau_n) e^{j[2\pi f_c(t-\tau_n) - \gamma_n]}$$

Complex envelope

The (lowpass) impulse response of the discrete channel *h(τ,t), is therefore* characterized by several discrete paths—each having a specific delay and attenuation.
Signal fading occurs due to destructive or constructive addition of a large number of phasors. If *h(τ,t) is modeled as a zero mean Gaussian process, the envelope |h(τ, t)| at* any time is Rayleigh-distributed.

Doppler spectrum

- The transform of *h(τ,τ) with respect to time, gives* the spectrum of time variation S(τ,ν), generally referred to as delay-Doppler spread function [1]. The variable ν represents the Doppler frequency shift due to changes in the electrical path length as a result of mobile movement. For two vertically polarized transmit and receive antennas and horizontal propagation of plane waves [2], the Doppler spectrum is:

$$S(\nu) = \frac{1}{2\pi\nu_m\sqrt{1-\left(\frac{\nu}{\nu_m}\right)^2}}\ ;\ \nu \le |\nu_m|$$

$$S(\nu) = 0\ ;\ \nu > |\nu_m|$$

$$\nu_m = \frac{V}{c} f_c$$

is the maximum Doppler shift due to vehicle speed

Rician spectrum

- When a direct path exists the spectrum is Rician and is given by:

$$S(\nu) = \frac{k_1}{2\pi \nu_m \sqrt{1 - \left(\frac{\nu}{\nu_m}\right)^2}} + k_2 \delta(\nu - k_3 \nu_m) \; ; \; \nu \leq |\nu_m|$$

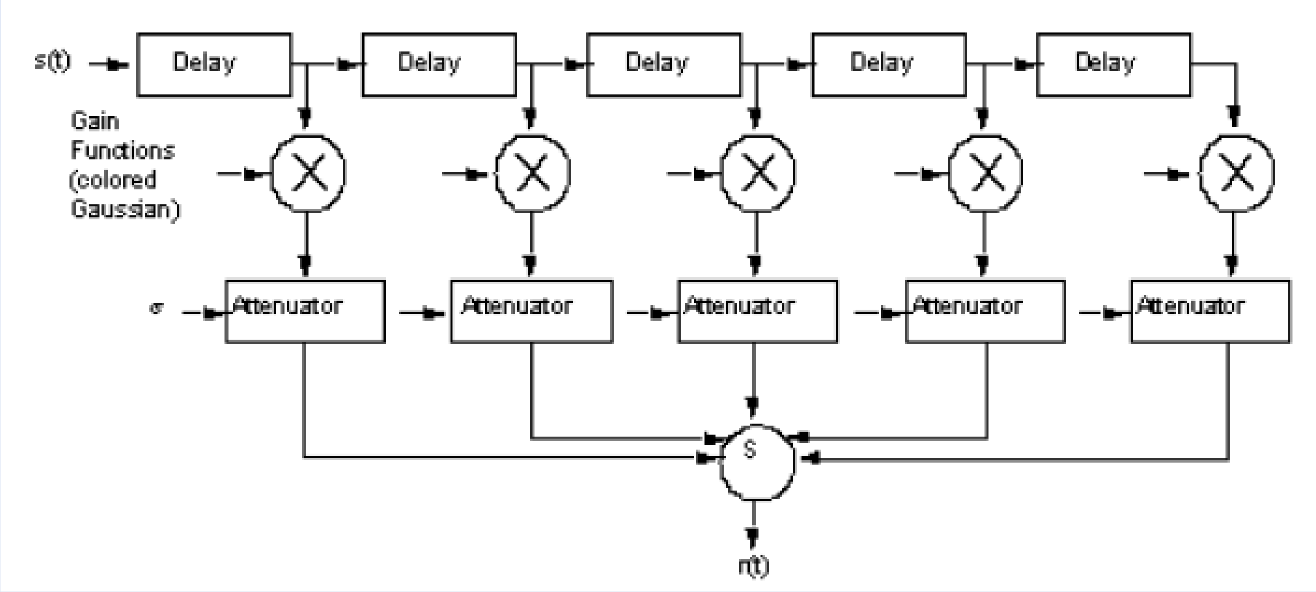
with k1, k2, k3 constants related to proportion of direct and scattered signal and the direct wave angle of arrival. Assuming the wide sense stationary uncorrelated scattering (WSSUS) [3], the average delay profiles and Doppler spectra information is needed for the simulation of radio channel. Delay profiles [4] P(τ) can be measured (or approximated) as:

$$P(\tau) = \sum_n \sigma_n^2 \delta(\tau - \tau_n)$$

σ_n^2 the power associated with each path

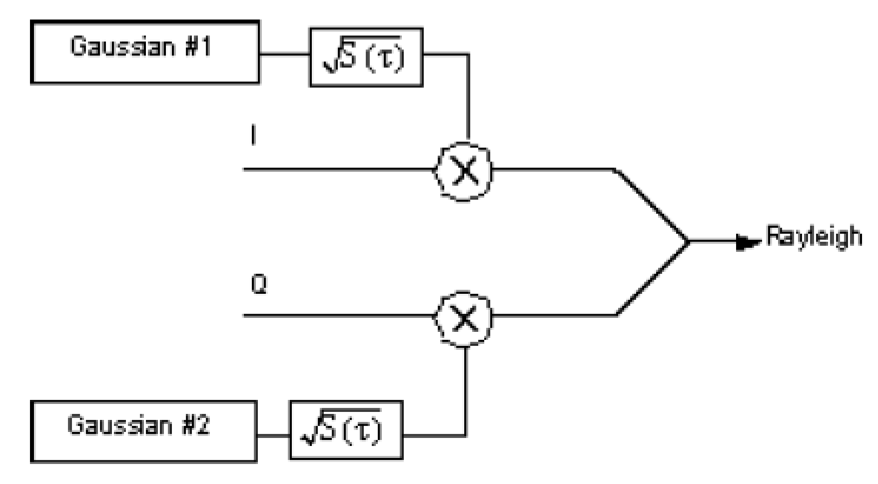
ADS schematics

- Assuming a uniform distribution of independent scatterers in the horizontal plane, each with a Doppler shift relative to the velocity of the mobile, the delay-Doppler spread function *S(τ, ν) and the impulse response of the channel can be constructed. A* wide-band, *frequency selective, multipath fading model can therefore be constructed* using a tapped-delay-line filter.



Jakes model in ADS

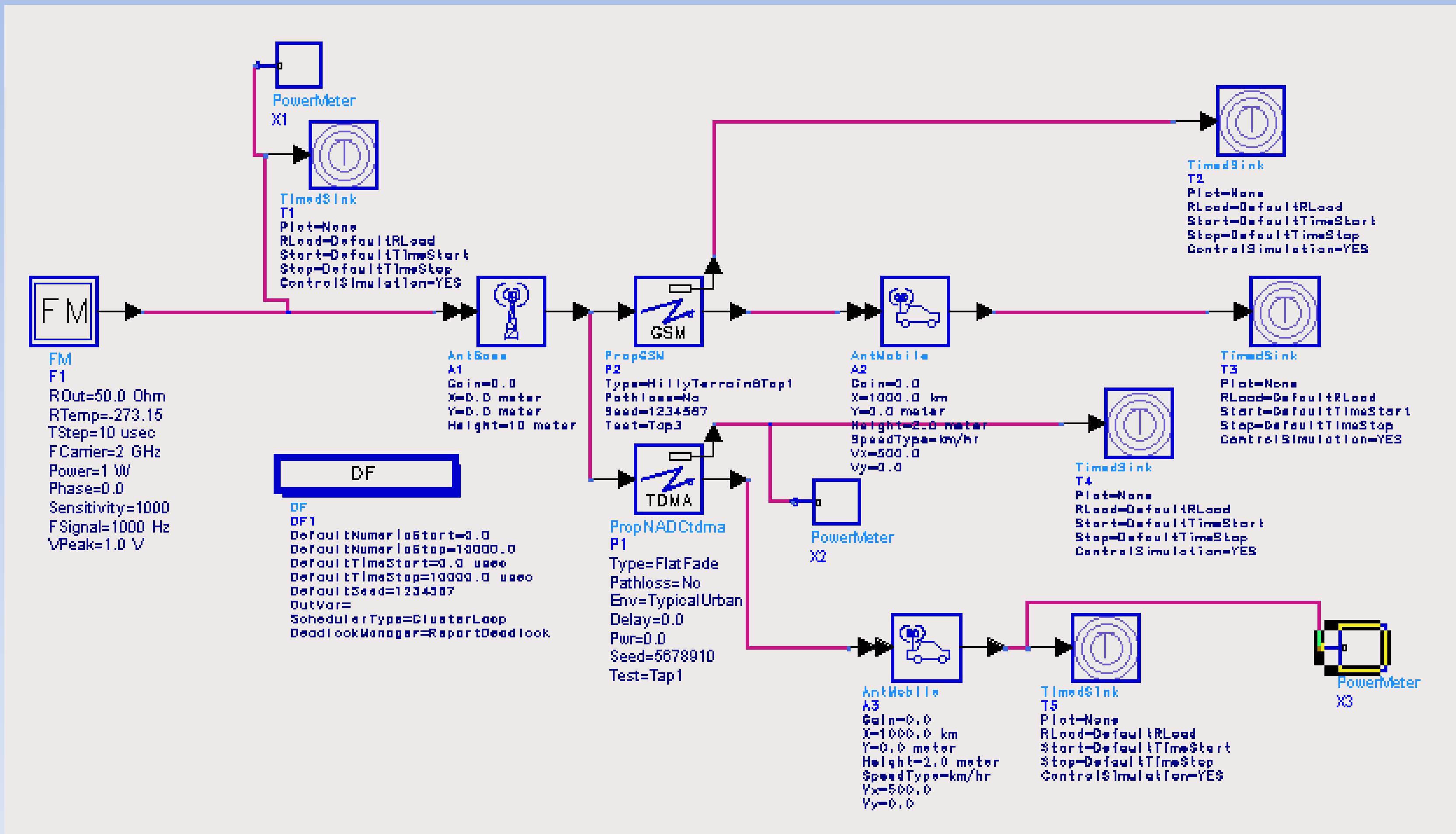
- To generate a Rayleigh fading profile for each path, independent AWGN sources (in cascade with a filter representing the effects of Doppler spread) can be used;
- Jakes [5] proposes a more efficient alternative ; in Jakes' model a number of low-frequency oscillators are used to generate signals that are added together. The amplitude and phases of these oscillators are chosen so that the pdf of the resultant phase approximates to a uniform distribution. The spectrum of the resulting complex function approximates the Doppler spectrum.



ADS channel models aspects

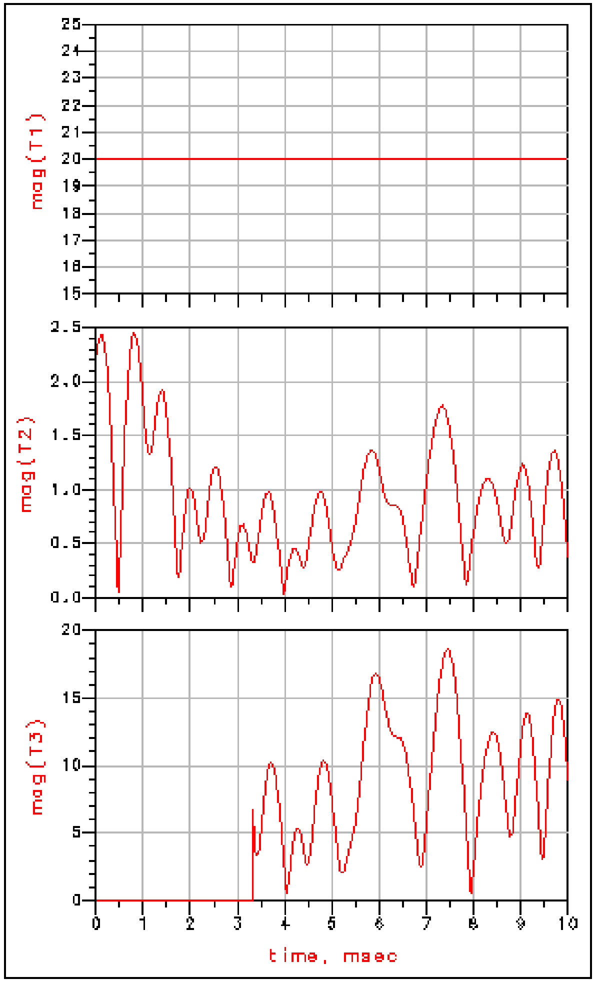
- Antenna and propagation models simulate radio channel effects on the transmitted signal. These effects include signal fading and pathloss. Both antenna and propagation channel models are TSDF components with input and output timed signals.
- Antenna models are identified by their coordinate and gain. For mobile antennas, the velocity vector is also included in the parameters. Multiple antenna inputs provide flexibility for adding contributions from various noise or fading channels. The propagation channel models are typically identified by the type of fading, the specification of power delay profile, and whether pathloss is to be activated.

GSM channel

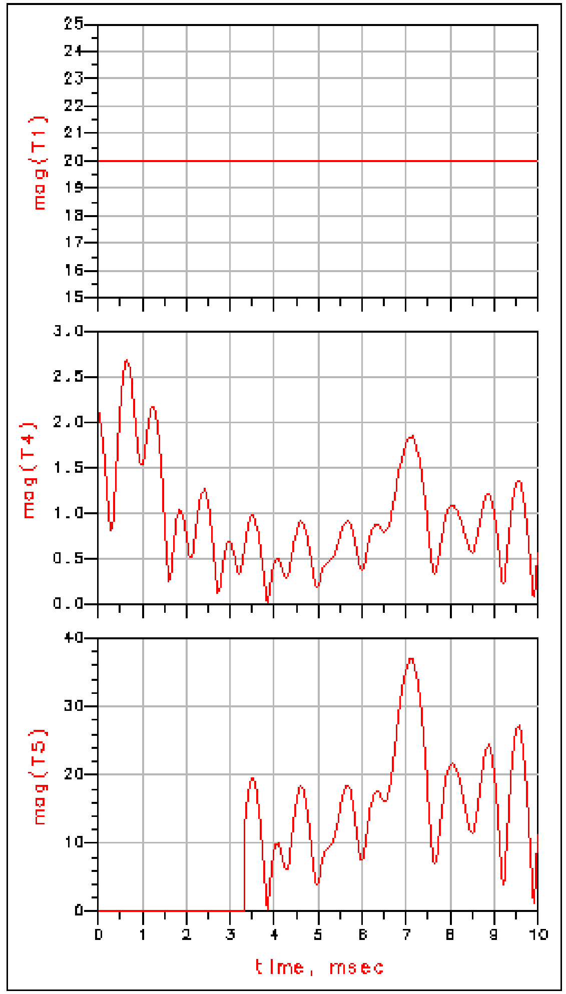


PowerMeter
X1
TimedSink
T1
Plot=None
RLoad=DefaultRLoad
Start=DefaultTimeStart
Stop=DefaultTimeStop
ControlSimulation=YES
FM
FM
F1
ROut=50.0 Ohm
RTemp=-273.15
TStep=10 usec
FCarrier=2 GHz
Power=1 W
Phase=0.0
Sensitivity=1000
FSignal=1000 Hz
VPeak=1.0 V
AntBase
A1
Gain=0.0
X=0.0 meter
Y=0.0 meter
Height=10 meter
GSM
PropGSM
P2
Type=HillyTerrain8Tap1
Pathloss=No
Seed=1234567
Test=Tap3
DF
DF
DF1
DefaultNumericStart=0.0
DefaultNumericStop=10000.0
DefaultTimeStart=0.0 usec
DefaultTimeStop=10000.0 usec
DefaultSeed=1234567
OutVar=
SchedulerType=ClusterLoop
DeadlockManager=ReportDeadlock
TDMA
PropNADCtdma
P1
Type=FlatFade
Pathloss=No
Env=TypicalUrban
Delay=0.0
Pwr=0.0
Seed=5678910
Test=Tap1
TimedSink
T2
Plot=None
RLoad=DefaultRLoad
Start=DefaultTimeStart
Stop=DefaultTimeStop
ControlSimulation=YES
AntMobile
A2
Gain=0.0
X=1000.0 km
Y=0.0 meter
Height=2.0 meter
SpeedType=km/hr
Vx=500.0
Vy=0.0
TimedSink
T3
Plot=None
RLoad=DefaultRLoad
Start=DefaultTimeStart
Stop=DefaultTimeStop
ControlSimulation=YES
PowerMeter
X2
TimedSink
T4
Plot=None
RLoad=DefaultRLoad
Start=DefaultTimeStart
Stop=DefaultTimeStop
ControlSimulation=YES
AntMobile
A3
Gain=0.0
X=1000.0 km
Y=0.0 meter
Height=2.0 meter
SpeedType=km/hr
Vx=500.0
Vy=0.0
TimedSink
T5
Plot=None
RLoad=DefaultRLoad
Start=DefaultTimeStart
Stop=DefaultTimeStop
ControlSimulation=YES
PowerMeter
X3

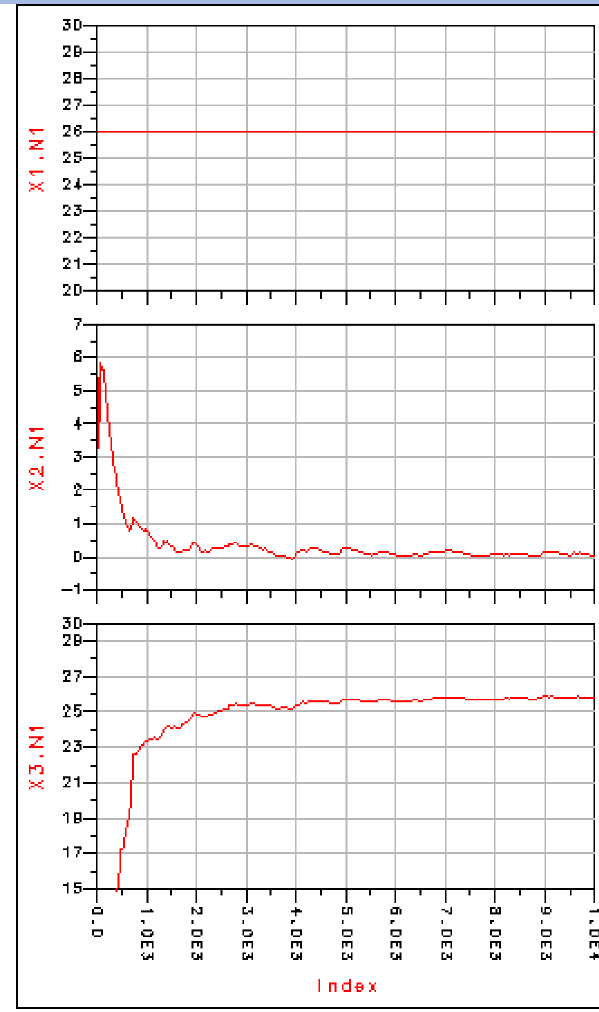
GSM channel results



Signal magnitude for input, gain function, and the output of GSM channel

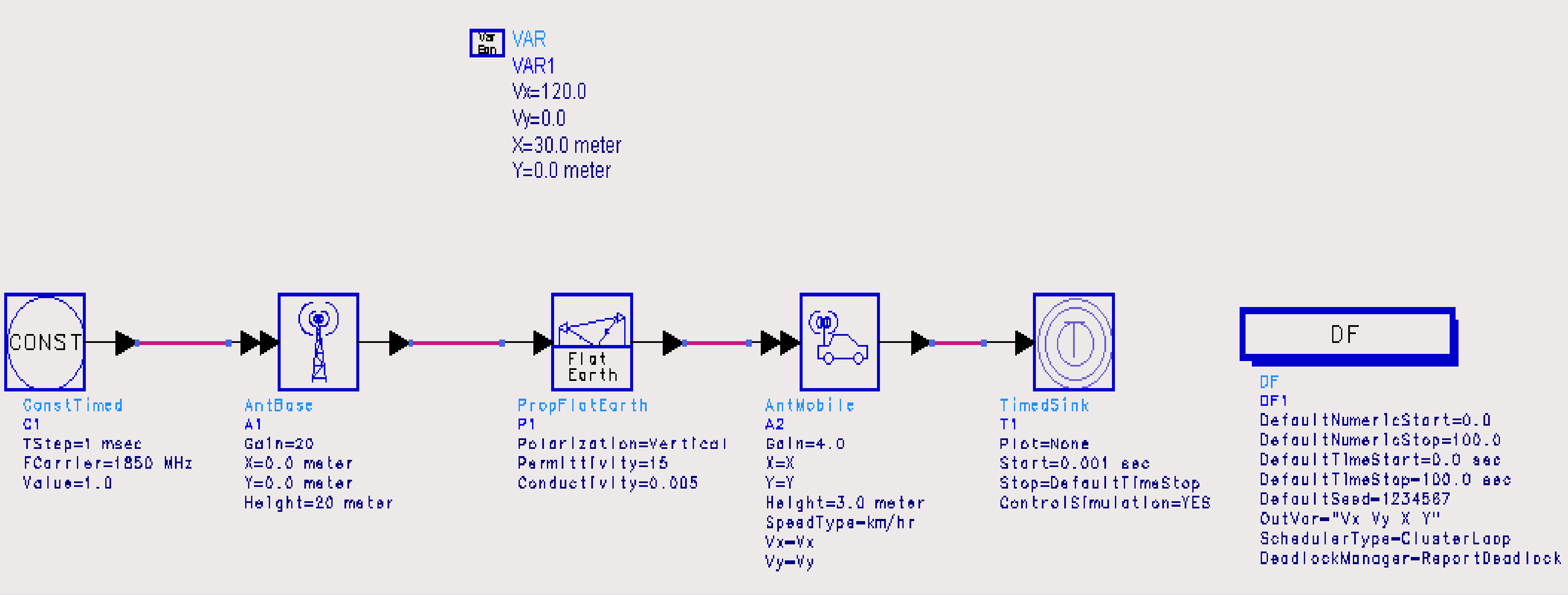


Signal magnitude for input, gain function, and the output of TDMA channel



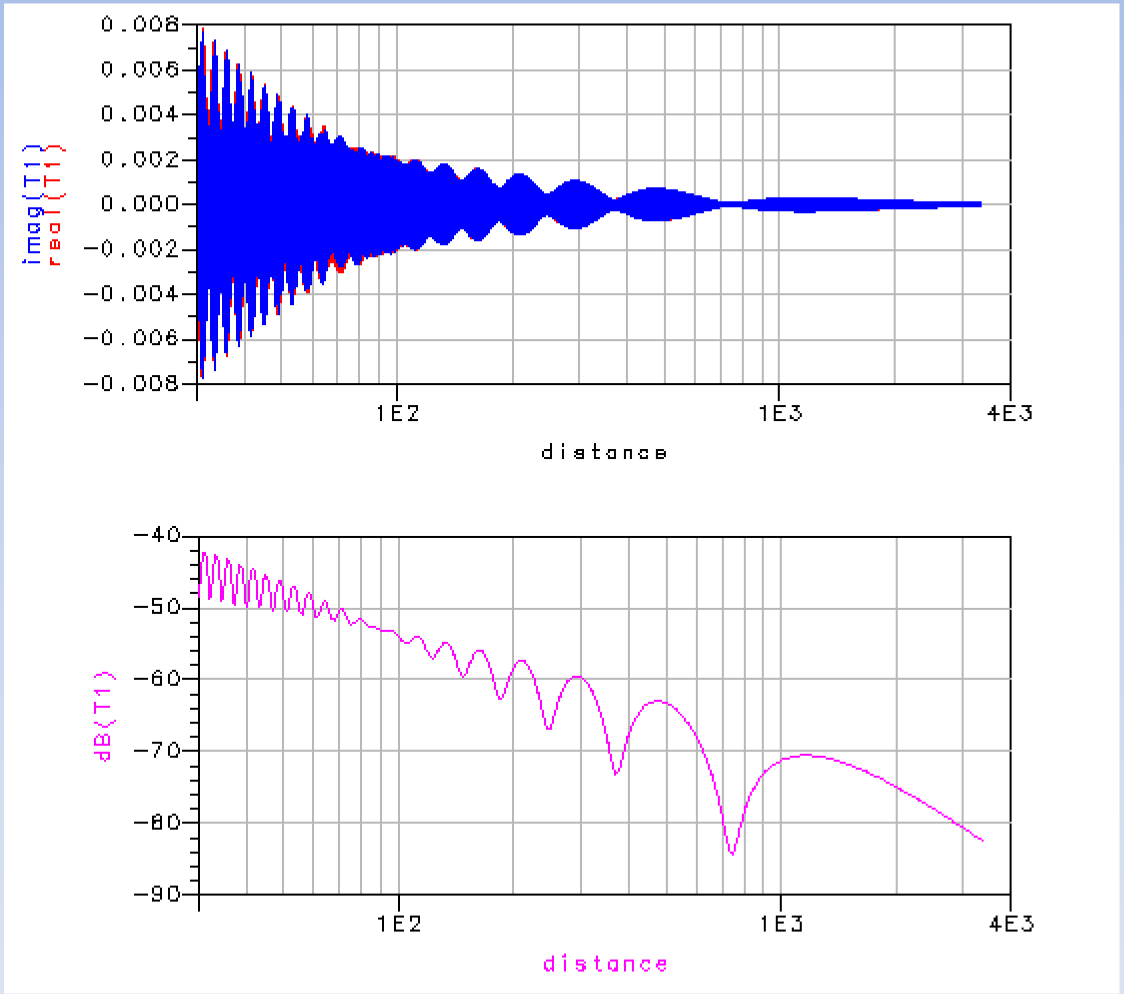
Time average power for input, gain function, and the output of TDMA channel

Flat-Earth channel



Flat-Earth channel

-Distance is in meters
- Speed is 120 Km/h
- Initial distance is 30 m
- Carrier frequency 1850 MHz



Envelope of the received signal in dB

- Deep fading is present between 100 – 1000 m

References

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- [2]R. H. Clarke, "A Statistical Theory of Mobile-Radio Reception," *The Bell System Technical Journal, July-August 1968.*
- [3]R. Steele, *Mobile Radio Communications, Pentech Press, 1992.*
- [4]GSM 05.05 Recommendation, *Radio Transmission and Reception.*
- [5]W. C. Jakes (Editor), *Microwave Mobile Communications, John Wiley & Sons,* 1974.
- [6]M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Radio," *IEEE Trans. VT-29, pp. 317-325, August 1980.*
- [7]Y. Okumura, "Field Strength and its Variability in VHF and UHF Land Mobile Service," *Review of Electrical Communication Laboratory, Vol 16, pp. 825-873,* Sep-Oct. 1968.
- [8] Agilent tutorials