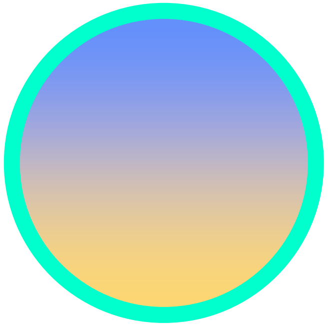
Chapter 4

Physical Principles of Propagation

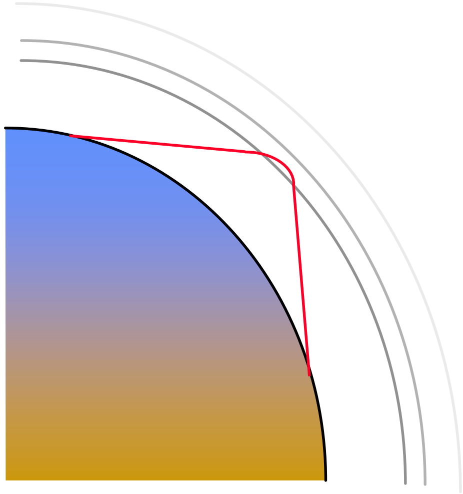
Introduction to Propagation

- Propagation is a key process within every radio link. During propagation, many processes act on the radio signal.
  - attenuation
    - the signal amplitude is reduced by various natural mechanisms; if there is too much attenuation, the signal will fall below the reliable detection threshold at the receiver. Attenuation is the most important single factor in propagation.
  - multipath and group delay distortions
    - the signal diffracts and reflects off irregularly shaped objects, producing a host of components which arrive in random timings and random RF phases at the receiver. This blurs pulses and also produces intermittent signal cancellation and reinforcement. These effects are combatted through a variety of special techniques
  - time variability - signal strength and quality varies with time, often dramatically
  - space variability - signal strength and quality varies with location and distance
  - frequency variability - signal strength and quality differs on different frequencies
- Effective masteryof propagation relies on
  - Physics: understand the basic propagation processes
  - Measurement: obtain data on propagation behavior in area of interest
  - Statistics: characterize what is known, extrapolate to predict the unknown
  - Modelmaking: formalize all the above into useful models

Propagation Effects of Earth’s Atmosphere

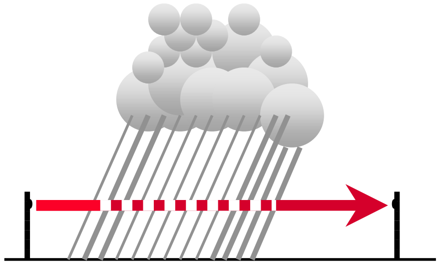


- Earth’s unique atmosphere supports life (ours included) and also introduces many propagation effects -- some useful, some troublesome
- Skywave Propagation: reflection from Ionized Layers
  - LF and HF frequencies (below roughly 50 MHz.) are routinely reflected off layers of the upper atmosphere which become ionized by the sun
  - this phenomena produces intermittent world-wide propagation and occasional total outages
  - this phenomena is strongly correlated with frequency, day/night cycles, variations in earth’s magnetic field, 11-year sunspot cycle
  - these effects are negligible for wireless systems at their much-higher frequencies

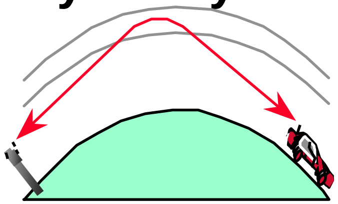


More Atmospheric Propagation Effects

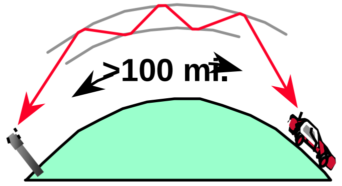
“Rain Fades” on MIcrowave Links



Refraction by air layers



Ducting by air layers



- Attenuation at Microwave Frequencies
  - rain droplets can substantially attenuate RF signals whose wavelengths are comparable to, or smaller than, droplet size
  - rain attenuations of 20 dB. or more per km. are possible
  - troublesome mainly above 10 GHz., and in tropical areas
  - must be considered in reliability calculations during path design
  - not major factor in wireless systems propagation
- Diffraction, Wave Bending, Ducting
  - signals 50-2000 MHz. can be bent or reflected at boundaries of different air density or humidity
  - phenomena: very sporadic unexpected long-distance propagation beyond the horizon. May last minutes or hours
  - can occur in wireless systems

Influence of Wavelength on Propagation

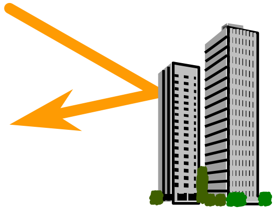
$$\lambda = C / F$$

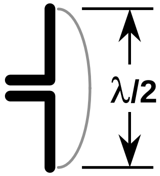
for AMPS: F= 870 MHz

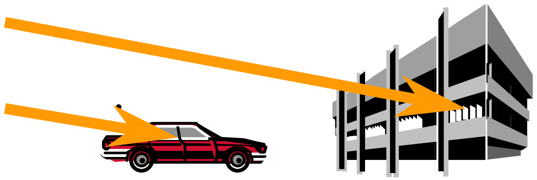
λ = 0.345 m = 13.6 inches

for PCS-1900: F = 1960 MHz

λ = 0.153 m = 6.0 inches



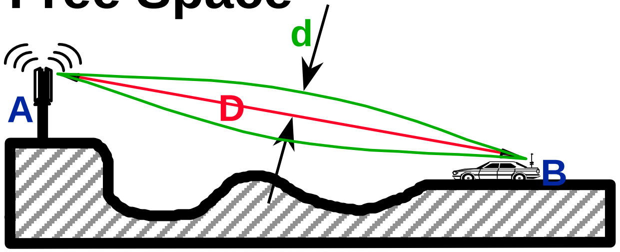




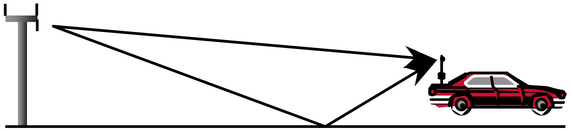
- Radio signals in the atmosphere propagate at almost speed of light
  - λ = wavelength
  - C = distance propagated in 1 second
  - F = frequency, Hertz
- The wavelength of a radio signal determines many of its propagation characteristics
  - Antenna elements size are typically in the order of 1/4 to 1/2 wavelength
  - Objects bigger than a wavelength can reflect or obstruct RF energy
  - RF energy can penetrate into a building or vehicle if they have apertures a wavelength in size, or larger

Dominant Mechanisms of Mobile Propagation

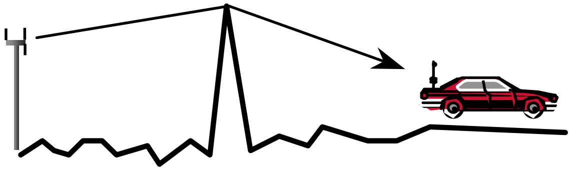
Free Space



Reflection with partial cancellation



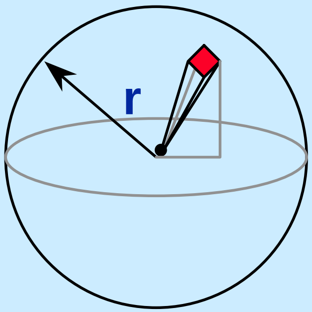
Knife-edge Diffraction



Most propagation in the mobile environment is dominated by these three mechanisms:

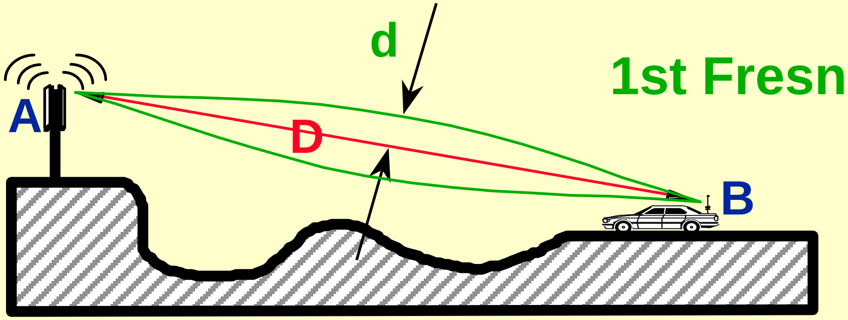
- **Free space**
  - No reflections, no obstructions
    - first Fresnel Zone clear
  - Signal spreading is only mechanism
  - Signal decays 20 dB/decade
- **Reflection**
  - Reflected wave 180°out of phase
  - Reflected wave not attenuated much
  - Signal decays 30-40 dB/decade
- **Knife-edge diffraction**
  - Direct path is blocked by obstruction
  - Additional loss is introduced
  - Formulae available for simple cases
- We'll explore each of these further...

Free-Space Propagation



Free Space “Spreading” Loss
energy intercepted by receiving antenna is proportional to **$1/r^2$**

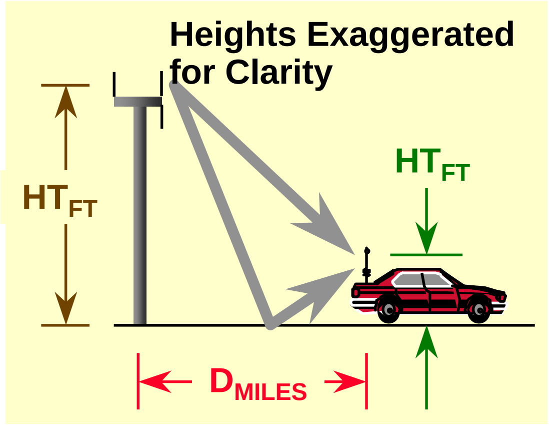
- **The simplest propagation mode**
  - Antenna radiates energy which spreads in space
  - Path Loss, db (between two *isotropic antennas*)
    $= 36.58 + 20 * \mathrm{Log}_{10}(F_{MHZ}) + 20 \mathrm{Log}_{10}(\mathrm{Dist}_{MILES})$
  - Path Loss, db (between two *dipole antennas*)
    $= 32.26 + 20 * \mathrm{Log}_{10}(F_{MHZ}) + 20 \mathrm{Log}_{10}(\mathrm{Dist}_{MILES})$
  - Notice the rate of signal decay:
  - **6 db per octave** of distance change, which is **20 db per decade** of distance change
- **Free-Space propagation is applicable if:**
  - there is only one signal path (no reflections)
  - the path is unobstructed (i.e., first Fresnel zone is not penetrated by obstacles)



1st Fresnel Zone

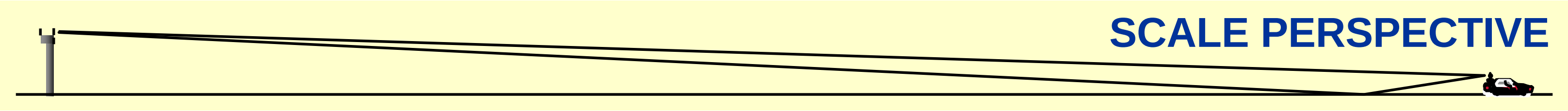
First Fresnel Zone =
{Points P where AP + PB - AB $< \lambda/2$ }
Fresnel Zone radius $d = 1/2\ (\lambda D)^\wedge{}^{(1/2)}$

Reflection With Partial Cancellation



- Mobile environment characteristics:
  - Small angles of incidence and reflection
  - Reflection is unattenuated (reflection coefficient =1)
  - Reflection causes phase shift of 180 degrees
- Analysis
  - Physics of the reflection cancellation predicts signal decay of **40 dB** per decade of distance

$$\text{Path Loss [dB]} = 172 + 34 \times \text{Log}(D_{Miles}) - 20 \times \text{Log}(\text{Base Ant. Ht}_{Feet}) - 10 \times \text{Log}(\text{Mobile Ant. Ht}_{Feet})$$

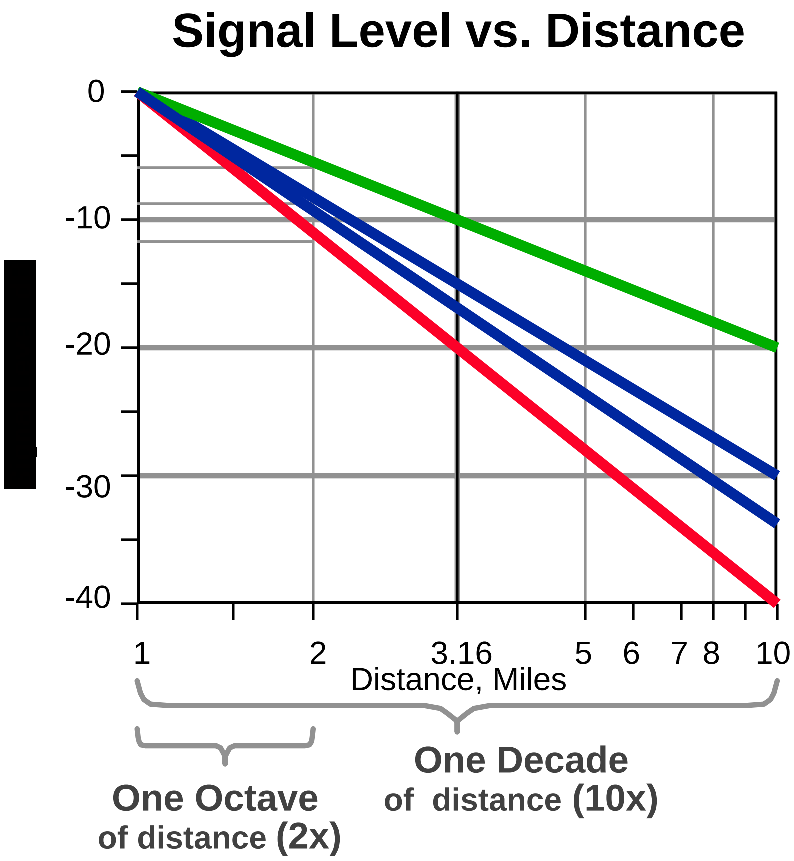


Comparison of Free-Space and Reflection Propagation Modes

Assumptions: Flat earth, TX ERP = 50 dBm, @ 1950 MHz. Base Ht = 200 ft, Mobile Ht = 5 ft.

$\text{Distance}_{\text{MILES}}$	1	2	4	6	8	10	15	20
Received Signal in Free Space, DBM	-52.4	-58.4	-64.4	-67.9	-70.4	-72.4	-75.9	-78.4
Received Signal in Reflection Mode	-69.0	-79.2	-89.5	-95.4	-99.7	-103.0	-109.0	-113.2

Signal Decay Rates in Various Environments



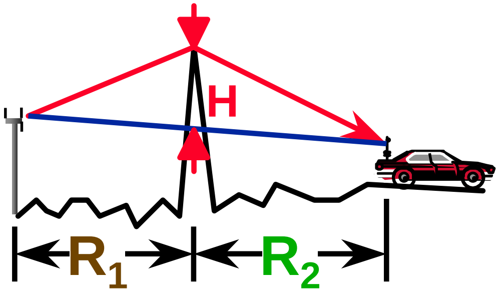
Signal Level vs. Distance

[redacted]

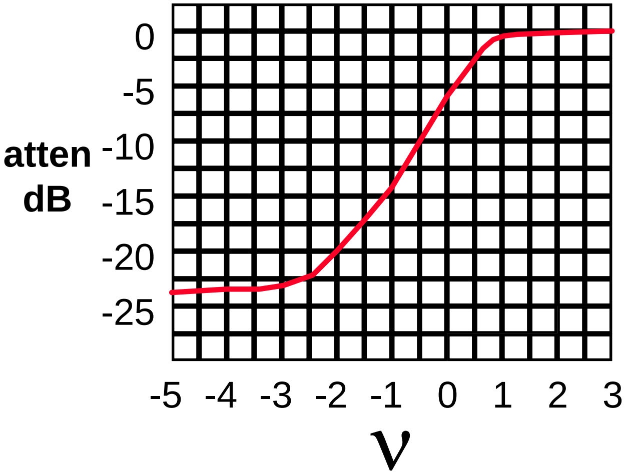
We've seen how the signal decays with distance in two basic modes of propagation:

- **Free-Space**
  - 20 dB per decade of distance
  - 6 db per octave of distance
- **Reflection Cancellation**
  - 40 dB per decade of distance
  - 12 db per octave of distance
- Real-life wireless propagation decay rates are typically somewhere between 30 and 40 dB per decade of distance

Knife-Edge Diffraction

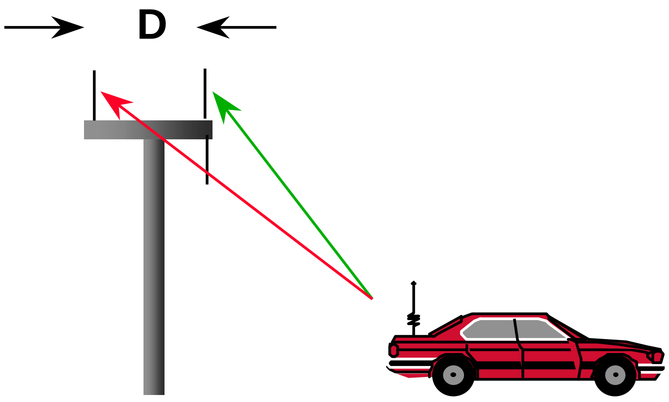


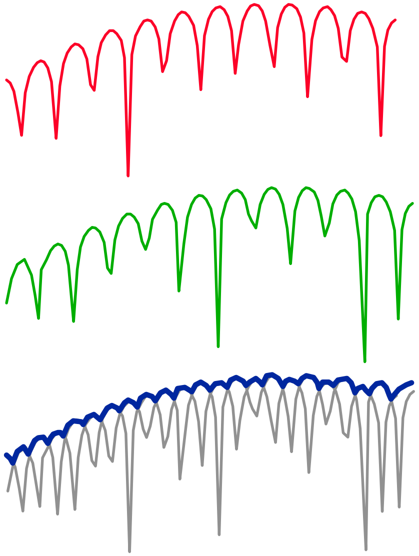
$$\nu = -H\sqrt{\frac{2}{\lambda}\left(\frac{1}{R_1}+\frac{1}{R_2}\right)}$$



- Sometimes a single well-defined obstruction blocks the path, introducing additional loss. This calculation is fairly easy and can be used as a manual tool to estimate the effects of individual obstructions.
- First calculate the diffraction parameter ν from the geometry of the path
- Next consult the table to obtain the obstruction loss in db
- Add this loss to the otherwise-determined path loss to obtain the total path loss.
- Other losses such as free space and reflection cancellation still apply, but computed independently for the path as if the obstruction did not exist

Combating Rayleigh Fading: Space Diversity





Signal received by Antenna 1

Signal received by Antenna 2

Combined Signal

- Fortunately, Rayleigh fades are very short and last a small percentage of the time
- Two antennas separated by several wavelengths will not generally experience fades at the same time
- “Space Diversity” can be obtained by using two receiving antennas and switching instant-by-instant to whichever is best
- Required separation **D** for good decorrelation is 10-20λ
  - 12-24 ft. @ 800 MHz.
  - 5-10 ft. @ 1900 MHz.

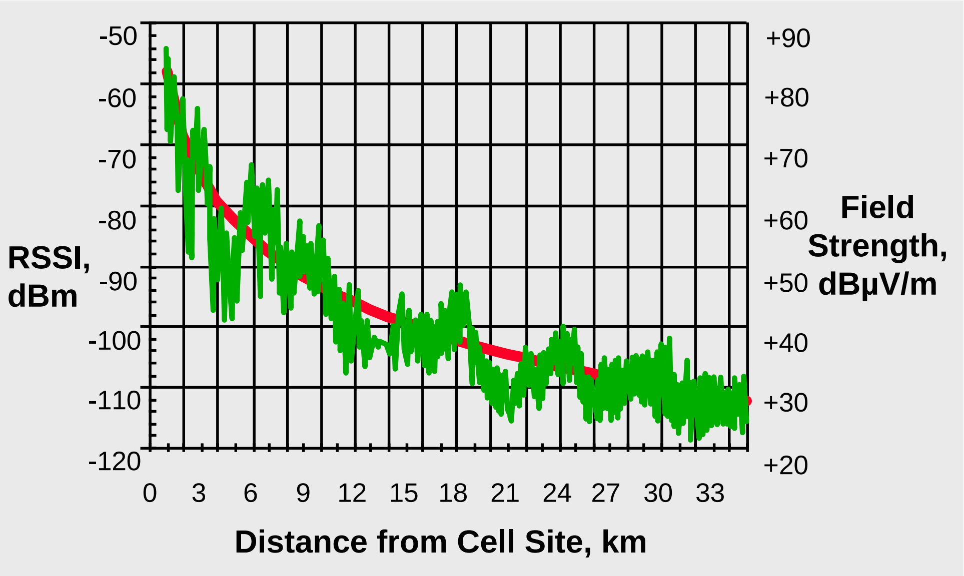
Types Of Propagation Models And Their Uses

- Simple ***Analytical*** models
  - Used for understanding and predicting individual paths and specific obstruction cases
- General ***Area*** models
  - Primary drivers: statistical
  - Used for early system dimensioning (cell counts, etc.)
- ***Point-to-Point*** models
  - Primary drivers: analytical
  - Used for detailed coverage analysis and cell planning
- ***Local Variability*** models
  - Primary drivers: statistical
  - Characterizes microscopic level fluctuations in a given locale, confidence-of-service probability

Examples of various model types

- **Simple Analytical**
  - Free space (Friis formula)
  - Reflection cancellation
  - Knife-edge diffraction
- **Area**
  - Okumura-Hata
  - Euro/Cost-231
  - Walfisch-Betroni/Ikegami
- **Point-to-Point**
  - Ray Tracing
    - Lee's Method, others
  - Tech-Note 101
  - Longley-Rice, Biby-C
- **Local Variability**
  - Rayleigh Distribution
  - Normal Distribution
  - Joint Probability Techniques

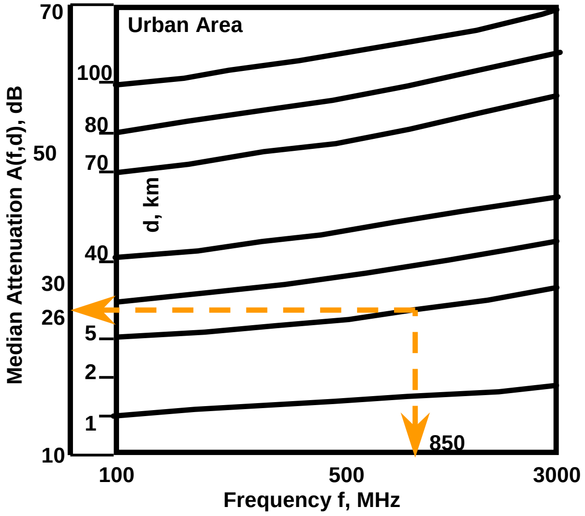
General Principles Of Area Models

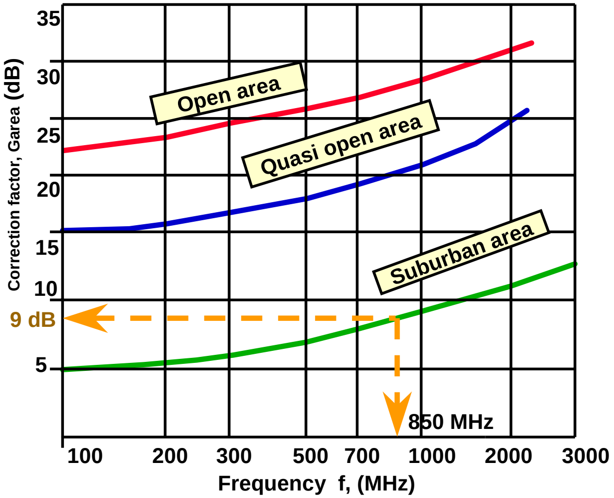


- **Green Trace** shows actual measured signal strengths on a drive test radial, as determined by real-world physics.
- **Red Trace** shows the Okumura-Hata prediction for the same radial. The smooth curve is a good “fit” for real data. However, the signal strength at a specific location on the radial may be much higher or much lower than the simple prediction.

- Area models mimic an *average path* in a defined area
- They’re based on measured data alone, with no consideration of individual path features or physical mechanisms
- Typical inputs used by model:
  - Frequency
  - Distance from transmitter to receiver
  - Actual or effective base station & mobile heights
  - Average terrain elevation
  - Morphology correction loss (Urban, Suburban, Rural, etc.)
- Results may be quite different than observed on individual paths in the area

The Okumura Model: General Concept





The Okumura model is based on detailed analysis of exhaustive drive-test measurements made in Tokyo and its suburbs during the late 1960's and early 1970's. The collected date included measurements on numerous VHF, UHF, and microwave signal sources, both horizontally and vertically polarized, at a wide range of heights.

The measurements were statistically processed and analyzed with respect to almost every imaginable variable. This analysis was distilled into the curves above, showing a median attenuation relative to free space loss **Amu (f,d)** and correlation factor **Garea (f,area), for** BS antenna height **ht = 200 m** and MS antenna height **hr = 3 m.**

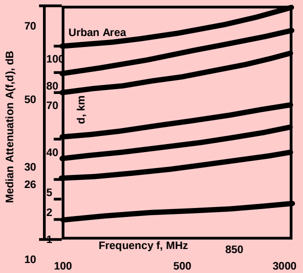
Okumura has served as the basis for high-level design of many existing wireless systems, and has spawned a number of newer models adapted from its basic concepts and numerical parameters.

Structure of the Okumura Model

$$\text{Path Loss [dB]} = L_{FS} + A_{mu}(f,d) - G(H_b) - G(H_m) - G_{area}$$

Free-Space Path Loss

$A_{mu}(f,d)$ Additional Median Loss from Okumura's Curves

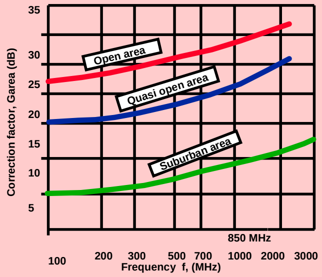


Base Station Height Gain
$= 20 \times \text{Log}(H_b/200)$

Mobile Station Height Gain
$= 10 \times \text{Log}(H_m/3)$

Morphology Gain

0	dense urban
5	urban
10	suburban
17	rural



- The Okumura Model uses a combination of terms from basic physical mechanisms and arbitrary factors to fit 1960-1970 Tokyo drive test data
- Later researchers (HATA, COST231, others) have expressed Okumura's curves as formulas and automated the computation

The Hata Model: General Concept

- The *Hata* model is an empirical formula for propagation loss derived from *Okumura's* model, to facilitate automatic calculation.
- The propagation loss in an urban area is presented in a simple general format **A + B x log R**, where **A** and **B** are functions of frequency and antenna height, **R** is distance between BS and MS antennas
- The model is applicable to frequencies **100 MHz-1500 MHz**, distances **1-20 km**, BS antenna heights **30-200 m**, MS antenna heights **1-10 m**
- The model is simplified due to following limitations:
  - Isotropic antennas
  - Quasi-smooth (not irregular) terrain
  - Urban area propagation loss is presented as the **standard** formula
  - Correction equations are used for other areas
- Although Hata model does not imply *path-specific corrections*, it has significant practical value and provide predictions which are very closely comparable with Okumura's model

Hata Model General Concept and Formulas

(1) $L_{HATA}\,(\mathit{urban})\ [dB] = 69.55 + 26.16 \times \log(f) + [\,44.9 - 6.55 \times \log(h_b)\,] \times \log(d) - 13.82 \times \log(h_b) - A(h_m)$

(2) $L_{HATA}\,(\mathit{suburban})\ [dB] = L_{HATA}\,(\mathit{urban}) - 2 \times [\,\log(f/28)\,]^2 - 5.4$

(3) $L_{HATA}\,(\mathit{rural})\ [dB] = L_{HATA}\,(\mathit{urban}) - 4.78 \times [\,\log(f)\,]^2 - 18.33 \times \log(f) - 40.98$

(4) $A(h_m)\ [dB] = [\,11 \times \log(f) - 0.7\,] \times h_m - [\,1.56 \times \log(f) - 0.8\,]$

(5) $A(h_m)\ [dB] = 8.29 \times [\,\log(1.54 \times h_m)\,]^2 - 1.1$ (for f<= 300 MHz.)

(6) $A(h_m)\ [dB] = 3.2 \times [\,\log(1175 \times h_m)\,]^2 - 4.97$ (for f > 300 MHz.)

Formulas for median path loss are:
- (1) - Standard formula for urban areas
- (2) - For suburban areas
- (3) - For rural areas

Formulas for MS antenna ht. gain correction factor A(hm)
- (4) - For a small to medium sizes cities
- (5) and (6) - For large cities

f - carrier frequency, MHz

h_b and h_m - BS and MS antenna heights, m

d - distance between BS and MS antennas, km

<u>Environmental Factor C</u>

0	dense urban
-5	urban
-10	suburban
-17	rural

The EURO COST-231 Model

$$L_{COST}\,(urban)\,[dB] = 46.3 + 33.9 \times \log(f) + [\,44.9 - 6.55 \times \log(h_b)\,] \times \log(d) + C_m - 13.82 \times \log(h_b) - A(h_m)$$

The COST-231 model was developed by European **CO**operative for **Scientific** and **T**echnical Research committee. It extends the HATA model to the 1.8-2 GHz. band in anticipation of PCS use.

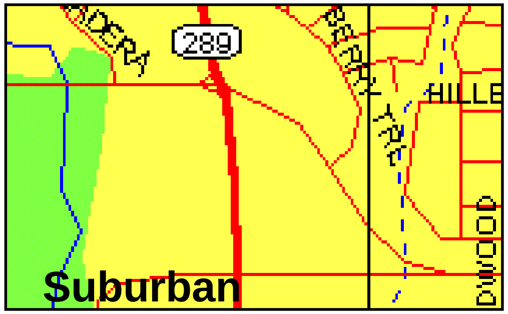
- COST-231 is applicable for frequencies **1500-2000 MHz**, distances **1-20 km**, BS antenna heights **30-200 m**, MS antenna heights **1-10 m**
- Parameters and variables:
  - **f** is carrier frequency , in MHz
  - **hb** and **hm** are BS and MS antenna heights (m)
  - **d** is BS and MS separation, in km
  - **A(hm)** is MS antenna height correction factor (same as in Hata model)
  - **Cm** is city size correction factor: **Cm=0 dB** for suburbs and **Cm=3 dB** for metropolitan centers

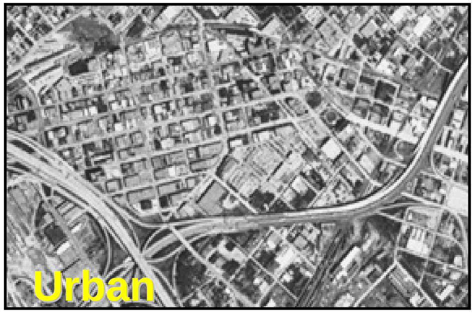
Environmental Factor C

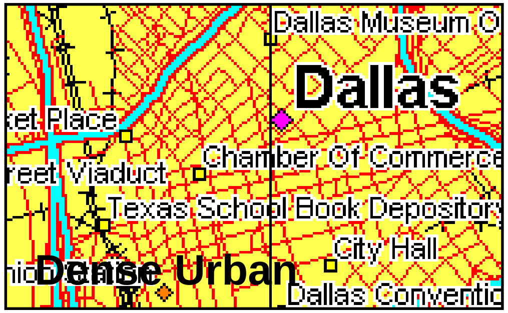
1900

-2	dense urban
-5	urban
-10	suburban
-26	rural

Examples of Morphological Zones



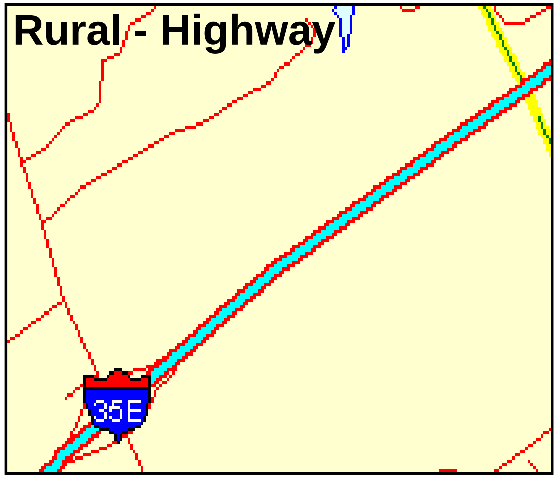


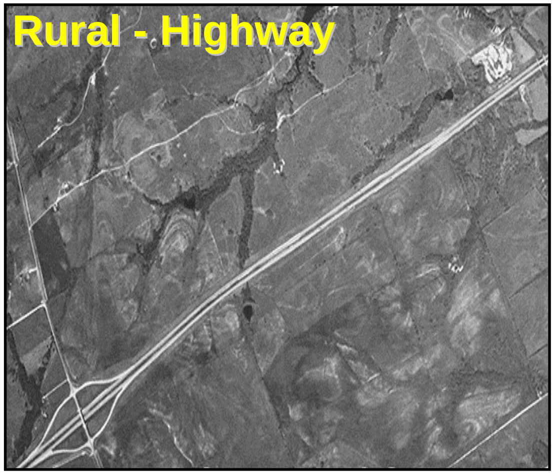


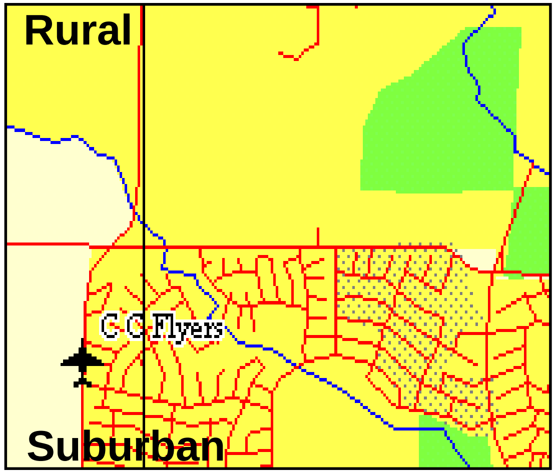
- **Suburban**: Mix of residential and business communities. Structures include 1-2 story houses 50 feet apart and 2-5 story shops and offices.
- **Urban**: Urban residential and office areas (Typical structures are 5-10 story buildings, hotels, hospitals, etc.)
- **Dense Urban**: Dense business districts with skyscrapers (10-20 stories and above) and high-rise apartments

Although zone definitions are arbitrary, the examples and definitions illustrated above are typical of practice in North American PCS designs.

Example Morphological Zones







- **Rural - Highway**: Highways near open farm land, large open spaces, and sparsely populated residential areas. Typical structures are 1-2 story houses, barns, etc.
- **Rural - In-town**: Open farm land, large open spaces, and sparsely populated residential areas. Typical structures are 1-2 story houses, barns, etc.

Notice how different zones may abruptly adjoin one another. In the case immediately above, farm land (rural) adjoins built-up subdivisions (suburban) -- same terrain, but different land use, penetration requirements, and anticipated traffic densities.

The MSI Planet General Model

$$P_r = P_t + K_1 + k_2 \log(d) + k_3 \log(H_b) + K_4\,DL + K_5 \log(H_b) \log(d)$$
$$+ K_6 \log(H_m) + K_c + K_o$$

P_r - received power (dBm)
P_t - transmit ERP (dBm)
H_b - base station effective antenna height
H_m - mobile station effective antenna height
DL - diffraction loss (dB)
K_1 - intercept
K_2 - slope
K_3 - correction factor for base station antenna height gain
K_4 - correction factor for diffraction loss (accounts for clutter heights)
K_5 - Okumura-Hata correction factor for antenna height and distance
K_6 - correction factor for mobile station antenna height gain
K_c - correction factor due to clutter at mobile station location
K_o - correction factor for street orientation

This is the general model format used in MSI’s popular PlaNET propagation prediction software for wireless systems. It includes terms similar to Okumura-Hata and COST-231 models, along with additional terms to include effects of specific obstructions and clutter on specific paths in the mobile environment.

Typical Model Results Including Environmental Correction

COST-231/Hata

f =1900 MHz.

	Tower Height, m	EIRP (watts)	C, dB	Range, km
Dense Urban	30	200	0	2.52
Urban	30	200	-5	3.50
Suburban	30	200	-10	4.8
Rural	50	200	-17	10.3

Okumura/Hata

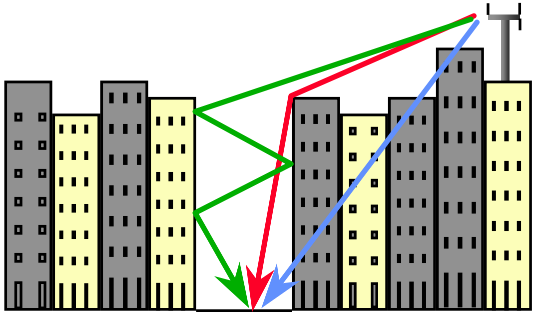
f = 870 MHz.

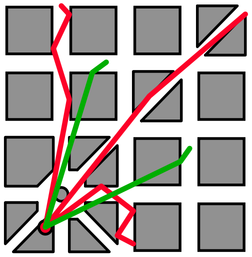
	Tower Height, m	EIRP (watts)	C, dB	Range, km
Dense Urban	30	200	-2	4.0
Urban	30	200	-5	4.9
Suburban	30	200	-10	6.7
Rural	50	200	-26	26.8

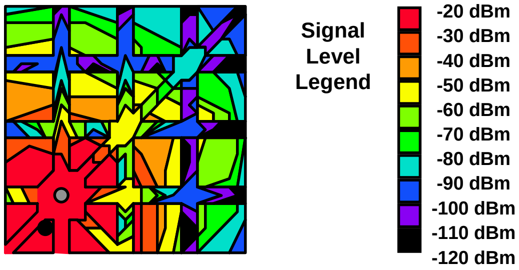
Propagation at 1900 MHz. vs. 800 MHz.

- Propagation at 1900 MHz. is similar to 800 MHz., but all effects are more pronounced.
  - Reflections are more effective
  - Shadows from obstructions are deeper
  - Foliage absorption is more attenuative
  - Penetration into buildings through openings is more effective, but absorbing materials within buildings and their walls attenuate the signal more severely than at 800 MHz.
- The net result of all these effects is to increase the "contrast" of hot and cold signal areas throughout a 1900 MHz. system, compared to what would have been obtained at 800 MHz.
- Overall, coverage radius of a 1900 MHz. BTS is approximately two-thirds the distance which would be obtained with the same ERP, same antenna height, at 800 MHz.

Walfisch-Betroni/Walfisch-Ikegami Models







- Ordinary Okumura-type models do work in this environment, but the Walfisch models attempt to improve accuracy by exploiting the actual propagation mechanisms involved

$$\textbf{Path Loss} = L_{FS} + L_{RT} + L_{MS}$$

L_{FS} = free space path loss (Friis formula)

L_{RT} = rooftop diffraction loss

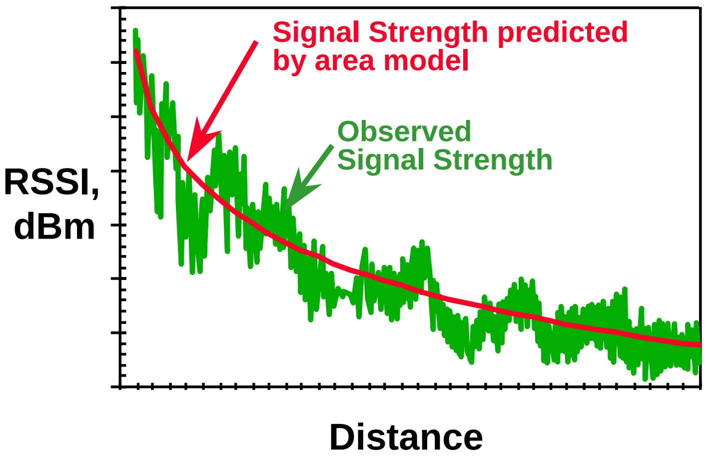
L_{MS} = multiscreen reflection loss

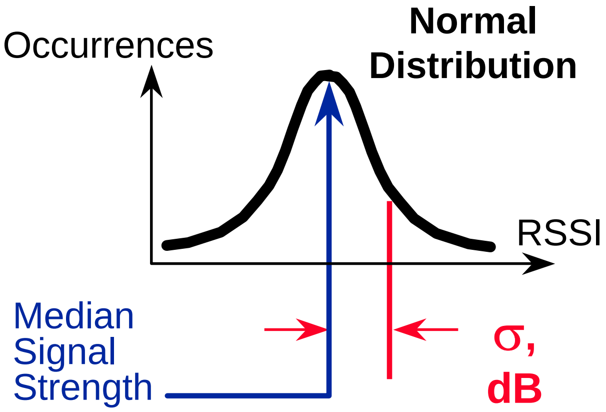
- Propagation in built-up portions of cities is dominated by ray *diffraction* over the tops of buildings and by ray *“channeling*” through multiple *reflections* down the street canyons

Statistical Techniques
Distribution Statistics Concept

- An area model predicts signal strength Vs. distance over an area
  - This is the *"median"* or most probable signal strength at every distance from the cell
  - The actual signal strength at any real location is determined by local physical effects, and will be higher or lower
  - It is feasible to measure the observed median signal strength **M** and standard deviation σ
  - **M** and σ can be applied to find probability of receiving an arbitrary signal level at a given distance

Signal Strength Predicted Vs. Observed

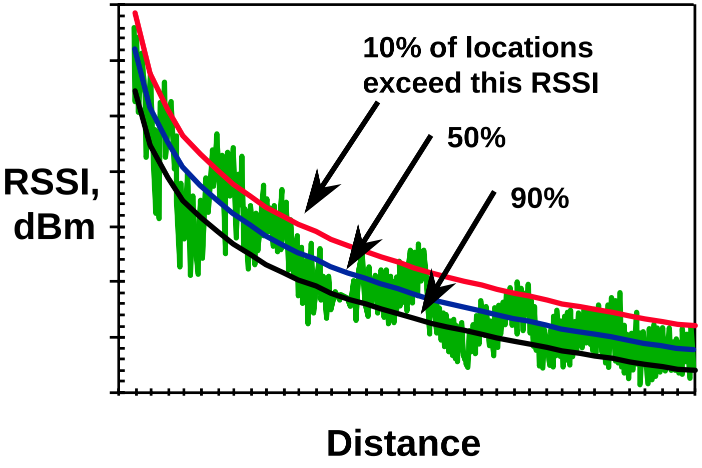


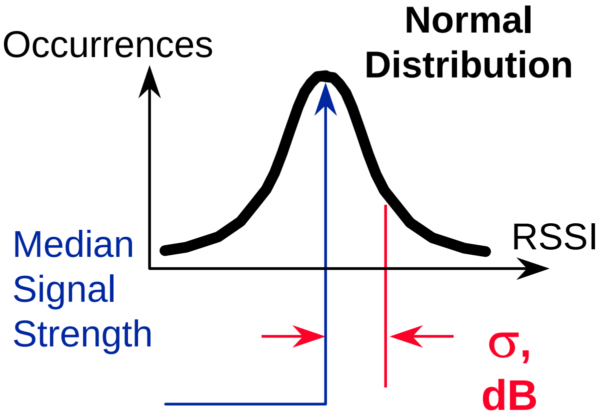


Statistical Techniques
Practical Application Of Distribution Statistics

- General Approach:
  - Use a model to predict RSSI
  - Compare measurements with model
    - obtain median signal strength **M**
    - obtain standard deviation σ
    - now apply correction factor to obtain field strength required for desired probability of service
- Applications: Given
  - A desired outdoor signal level (dbm)
  - The observed standard deviation σ from signal strength measurements
  - A desired percentage of locations which must receive that signal level
  - Compute a “cushion” in dB which will give us that % coverage confidence

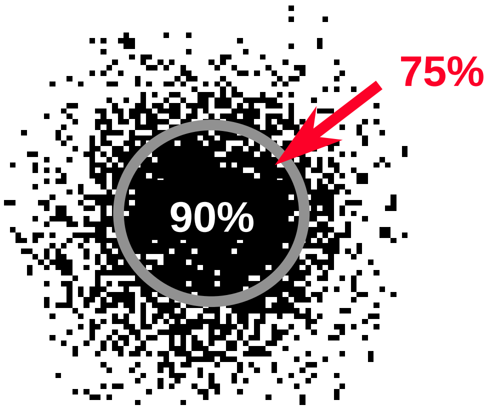
Percentage of locations where observed RSSI exceeds predicted RSSI





Cell Edge
Area Availability And Probability Of Service

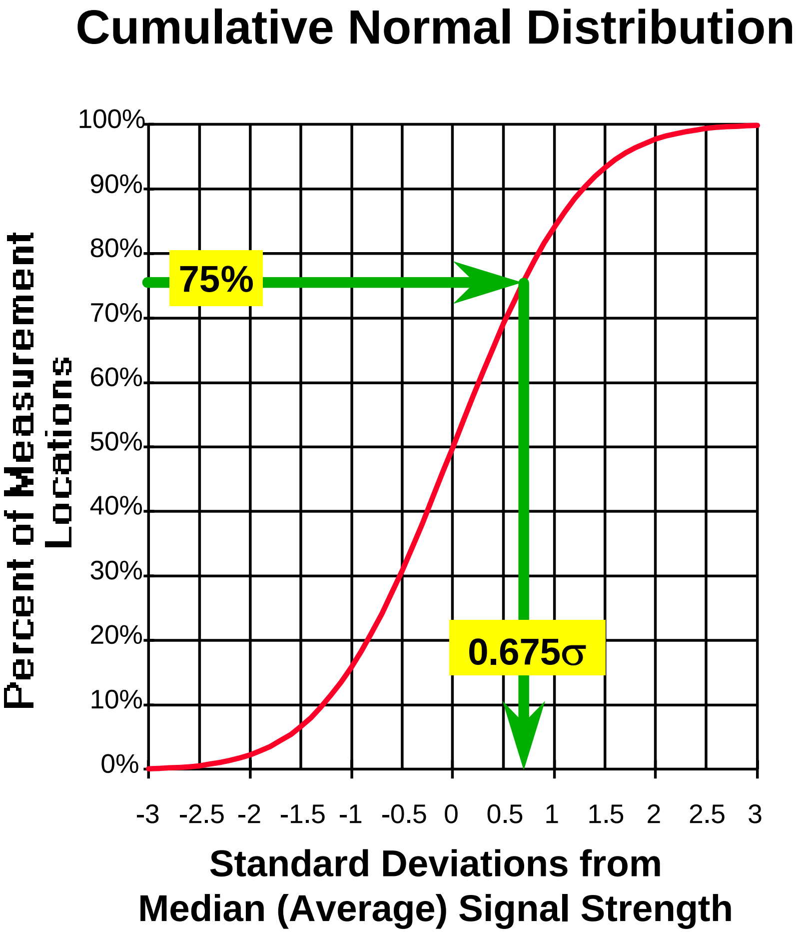
Statistical View of Cell Coverage



Area Availability:
90% overall within area
75%at edge of area

- Overall probability of service is best close to the BTS, and decreases with increasing distance away from BTS
- For overall 90% location probability within cell coverage area, probability will be 75% at cell edge
  - Result derived theoretically, confirmed in modeling with propagation tools, and observed from measurements
  - True if path loss variations are log-normally distributed around predicted median values, as in mobile environment
  - **90%/75%** is a commonly-used wireless numerical *coverage objective*
  - Recent publications by Nortel's Dr. Pete Bernardin describe the relationship between area and edge reliability, and the field measurement techniques necessary to demonstrate an arbitrary degree of coverage reliability

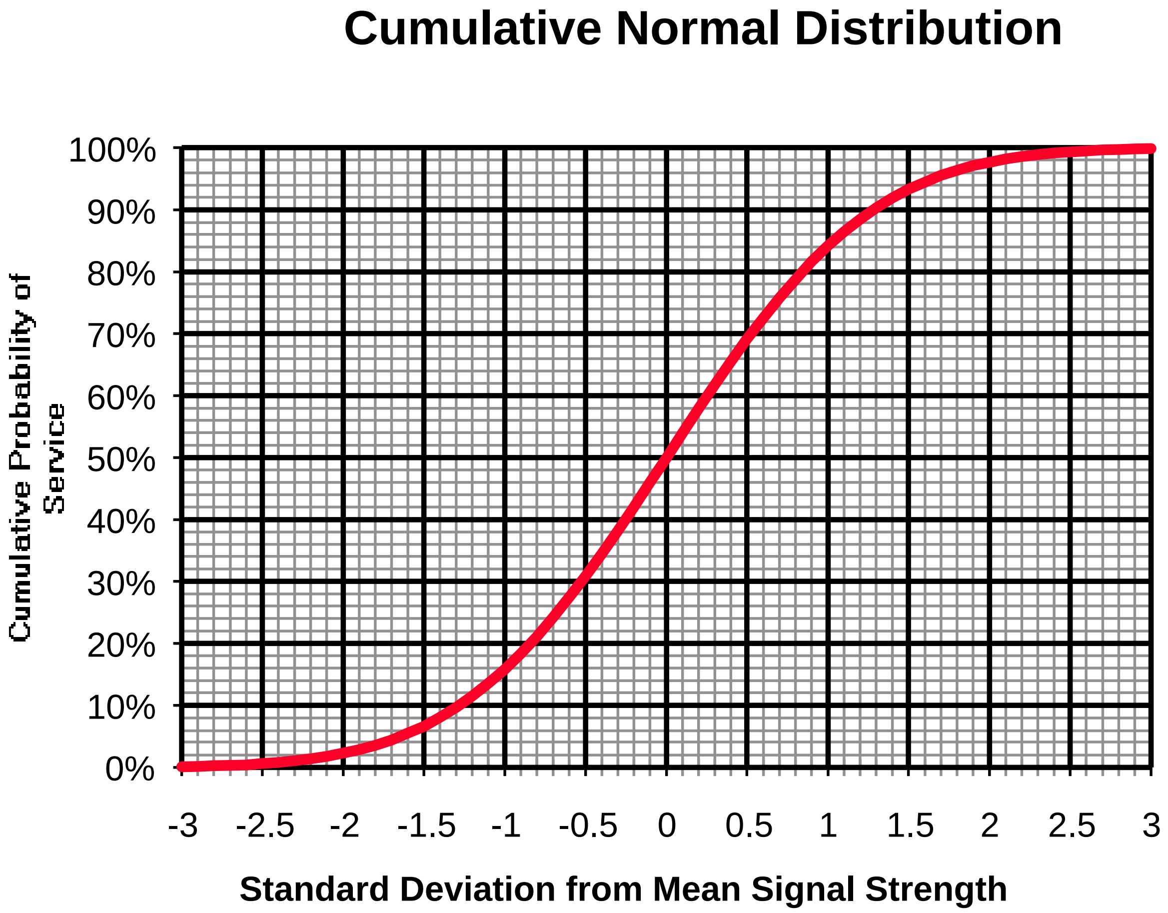
Application Of Distribution Statistics: Example



- Let’s design a cell to deliver at least **-95 dBm** to at least **75%** of the locations at the cell edge (*This will provide coverage to 90% of total locations within the cell*)
- Assume that measurements you have made show a **10 dB** standard deviation σ
- On the chart:
  - To serve **75%** of locations at the cell edge , we must deliver a median signal strength which is **.675** times σ stronger than **-95 dBm**
  - Calculate:
    - 95 dBm + (.675 x 10 dB)
    = - 88 dBm
  - So, design for a median signal strength of **-88 dBm!**

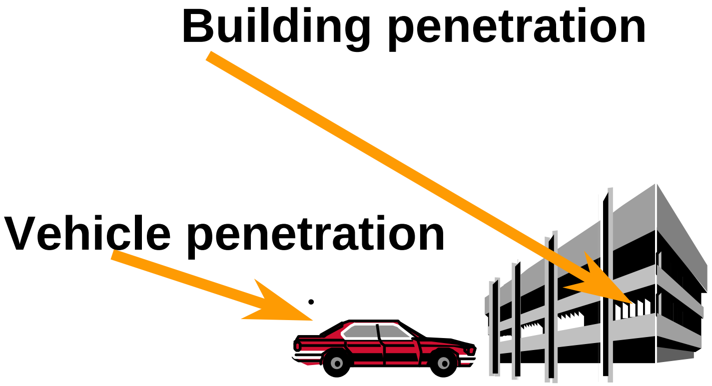
Statistical Techniques:

Normal Distribution Graph & Table For Convenient Reference



Standard Deviation	Cumulative Probability
-3.09	0.1%
-2.32	1%
-1.65	5%
-1.28	10%
-0.84	20%
-0.52	30%
0	50%
0.52	70%
0.675	75%
0.84	80%
1.28	90%
1.65	95%
2.35	99%
3.09	99.9%
3.72	99.99%
4.27	99.999%

Building Penetration
Statistical Characterization

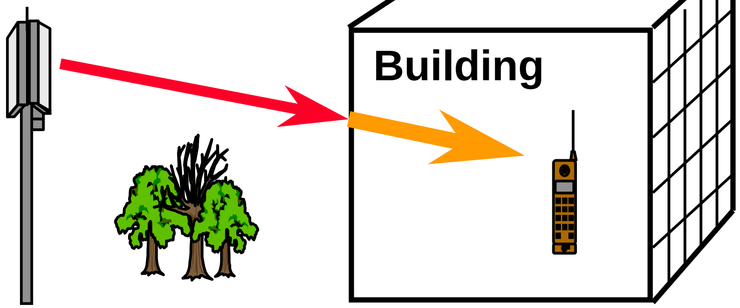


Typical Penetration Losses, dB compared to outdoor street level		
Environment Type ("morphology")	**Median Loss, dB**	**Std. Dev. σ, dB**
Dense Urban Bldg.	**20**	**8**
Urban Bldg.	**15**	**8**
Suburban Bldg.	**10**	**8**
Rural Bldg.	**10**	**8**
Typical Vehicle	**8**	**4**

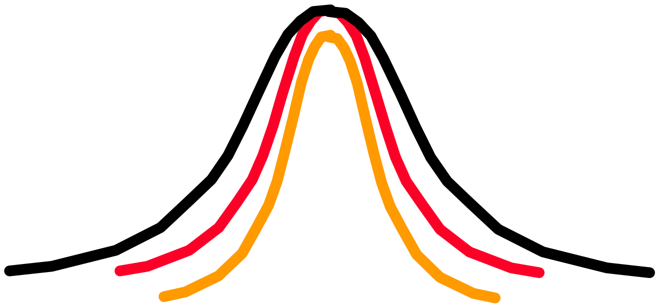
- Statistical techniques are effective against situations that are difficult to characterize analytically
  - Many analytical parameters, all highly variable and complex
- Building coverage is modeled using existing outdoor *path loss* plus an additional *"building penetration loss*"
  - *Median* value estimated/sampled
  - Statistical *distribution* determined
  - *Standard deviation* estimated or measured
  - Additional *margin* allowed in link budget to offset assumed loss
- Typical values are shown at left

Composite Probability Of Service

Adding Multiple Attenuating Mechanisms



Outdoor Loss + Penetration Loss



$$\sigma_{\mathrm{COMPOSITE}} = ((\sigma_{\mathrm{OUTDOOR}})^2+(\sigma_{\mathrm{PENETRATION}})^2)^{1/2}$$

$$\mathrm{LOSS}_{\mathrm{COMPOSITE}} = \mathrm{LOSS}_{\mathrm{OUTDOOR}}+\mathrm{LOSS}_{\mathrm{PENETRATION}}$$

- For an in-building user, the actual signal level includes regular outdoor path attenuation plus building penetration loss
- Both outdoor and penetration losses have their own variabilities with their own standard deviations
- The user’s overall composite probability of service must include composite median and standard deviation factors

Composite Probability of Service
Calculating Fade Margin For Link Budget

- *Example Case*: Outdoor attenuation σ is **8 dB**., and penetration loss σ is **8 dB**. Desired probability of service is **75%** at the cell edge
- What is the composite σ? How much fade margin is required?

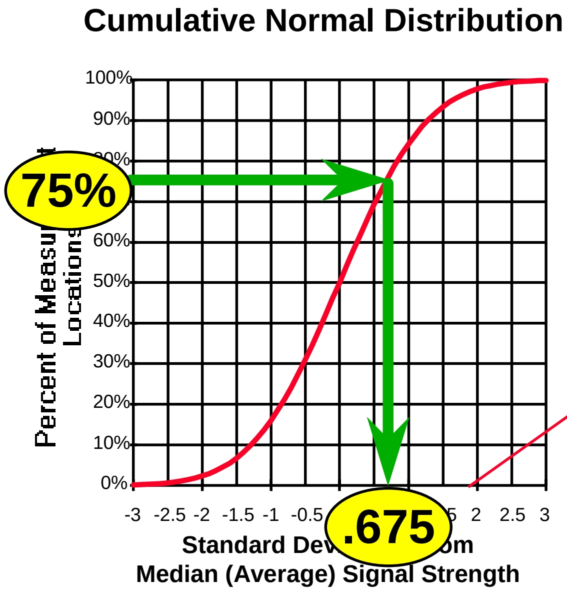
$\sigma_{COMPOSITE} = ((\sigma_{OUTDOOR})^2+(\sigma_{PENETRATION})^2)^{1/2}$

$= ((\mathbf{8})^2+(\mathbf{8})^2)^{1/2} = (\mathbf{64}+64)^{1/2} = (128)^{1/2} = \mathbf{11.31\ dB}$

On cumulative normal distribution curve, 75% probability is 0.675 σ above median.

Fade Margin required =

(11.31) • (0.675) = 7.63 dB.



Composite Probability of Service
Calculating Required Fade Margin

Environment Type ("morphology")	Building Penetration		Out-Door	Composite Total	
	Median Loss, dB	Std. Dev. σ, dB	Std. Dev. σ, dB	Area Availability Target, %	Fade Margin dB
Dense Urban Bldg.	20	8	8	90%/75% @edge	7.6
Urban Bldg.	15	8	8	90%/75% @edge	7.6
Suburban Bldg.	10	8	8	90%/75% @edge	7.6
Rural Bldg.	10	8	8	90%/75% @edge	7.6
Typical Vehicle	8	4	8	90%/75% @edge	6.0

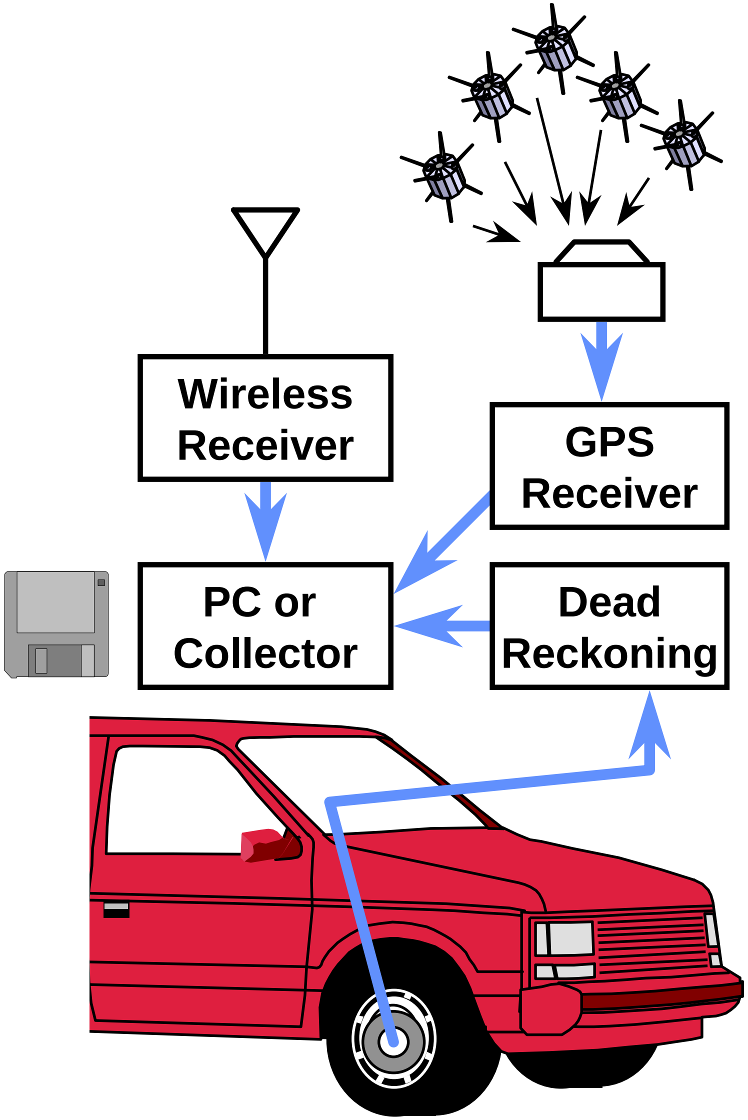
Propagation Data Collection Philosophy

- RF testing of sites is usually performed for one of two reasons:
- Drive Testing for model calibration
    - Prior to cell design of a wireless system, accurate models of propagation in the area must be developed for use by the prediction software. A significant number of typical sites are evaluated using the test transmitter and receiver to determine signal decay rates and to get a fairly accurate understanding of the effects of typical clutter in the area.
    - Tests are also conducted to evaluate the additional attenuation which the signal suffers during penetration of typical buildings and vehicles.
    - The focus is on developing models generally applicable to the area, not on the performance of specific individual sites.
- Drive Testing for site evaluation
    - Although propagation models for an area already have been refined, coverage of a particular site is so critical, or its environment so variable due to urban clutter, that it is essential to actually measure the coverage and interference it will produce. The focus is on this specific site.

Elements of Typical Measurement Systems

Main Features

- Field strength measurement
  - Accurate collection in real-time
  - Multi-channel, averaging capability
- Location Data Collection Methods:
  - Global Positioning System (GPS)
  - Dead reckoning on digitized map database using on-board compass and wheel revolutions sensor
  - A combination of both methods is recommended for the best results
- Ideally, a system should be calibrated in absolute units, not just raw received power level indications
  - Record normalized antenna gain, measured line loss



Typical Test Transmitter Operations

- Typical Characteristics
  - portable, low power needs
  - weatherproof or weather resistant
  - regulated power output
  - frequency-agile: synthesized
- Operational Concerns
  - spectrum coordination and proper authorization to radiate test signal
  - antenna unobstructed
  - stable AC power
  - SAFETY:
    - people/equipment falling due to wind, or tripping on obstacles
    - electric shock
    - damage to rooftop

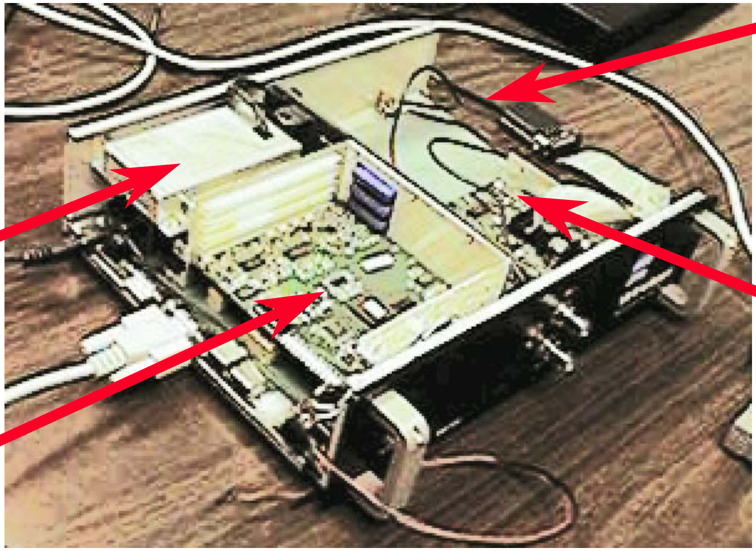
A Typical Mobile Test Receiver

- Receivers and decoders are installed only for the appropriate technologies and frequency bands
- Internal GPS or external GPS may be used, with or without dead-reckoning capabilities

Main On/Off

RF to Int. GPS

inputs to internal RXs



Up to 2 handsets may be connected for GSM or CDMA at 800 or 1900 MHz.

Internal GPS Receiver, if used

Up to 4 technology-specific decoder boards:
AMPS, TDMA
GSM, CDMA
Paging

Up to 4 technology and band-specific receivers:
800 MHz. cellular
150, 450, 800 Paging
1900 PCS

Selecting and Tuning Propagation Models

- Parameters of propagation models must be adjusted for best fit to actual drive-test measured data in the area where the model is applied
- The figure at right shows drive-test signal strengths obtained using a test transmitter at an actual test site
- Tools automate the process of comparing the measured data with its own predictions, and deriving error statistics
- Prediction model parameters then can be "tuned" to minimize observed error

PLANET V2.6 Mobile Systems International Plc. (/export/home/planet/planet_def)

Site Id:

Sector: 2

Width(km) 8.6

C: TRNG1900:3 -83dBm

C:

2:

C/I:

Total C/I:

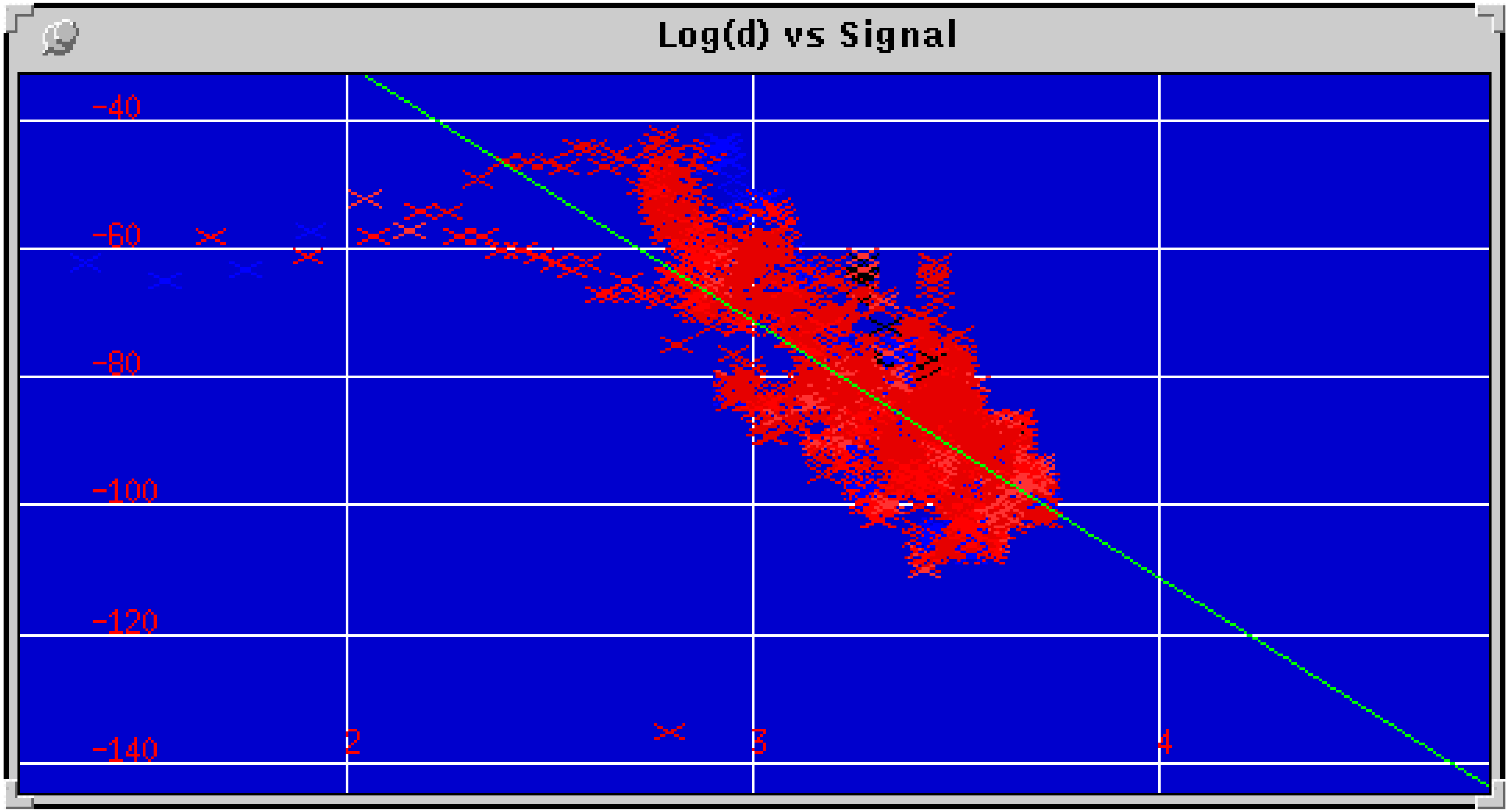
Number of Servers:

C/A:

Total C/A:

96 45'52.7"W 32 56'02.8"N

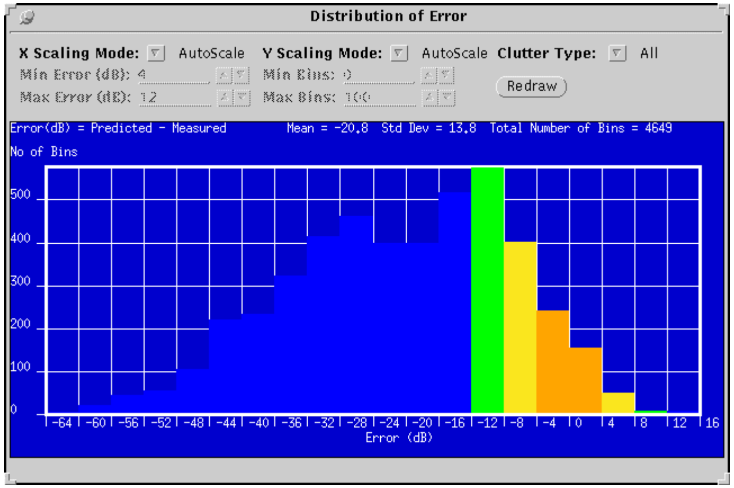
Measured Data vs. Model Predictions



- Is the propagation model approximately correct?
  - Is the data scatter small enough to justify use of a model?
  - correct slope to match data
  - correct position up/down on Y-axis?

Analysis of Measured vs. Predicted

- Several tools produce histograms showing the distribution of the differences between measured and predicted values
- The mean of the difference between predicted and measured is a very important quantity. It should be small (on order of a few dB).
- The standard deviation of the difference also should be small. If it is substantially larger than 8 dB., then either:
  - the environment is very diverse (perhaps it should be broken into pieces with separate models for better fit) or
  - the slope of the model is significantly different than the observed slope of the measurements (review the Sig. vs. Dist. graph)



Distribution of Error

X Scaling Mode: AutoScale **Y Scaling Mode:** AutoScale **Clutter Type:** All

Min Error (dB): 4

Max Error (dB): 12

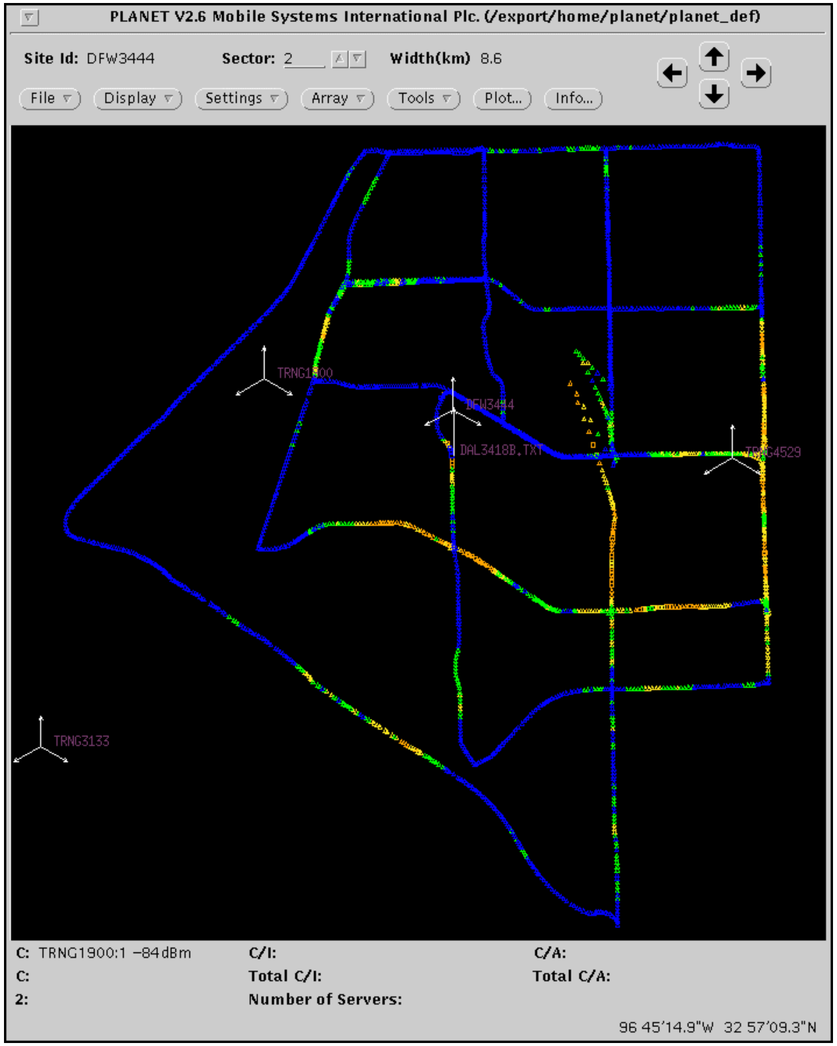
Min Bins: 0

Max Bins: 100

Error(dB) = Predicted - Measured Mean = -20.8 Std Dev = 13.8 Total Number of Bins = 4649

Displaying Error Distribution by Location

- Suppose a major hill blocked the signal in one direction, or the antenna pattern had an unexpected minimum in that direction
- This would cause the data in the shadowed region to differ substantially from data in all remaining directions
- Some tools can display the error values on a map like the one at right, to provide quick visual evidence for recognizing this type of problem



PLANET V2.6 Mobile Systems International Plc. (/export/home/planet/planet_def)

Site Id: DFW3444 **Sector:** 2 **Width(km)** 8.6

C: TRNG1900:1 −84dBm
C:
2:

C/I:
Total C/I:
Number of Servers:

C/A:
Total C/A:

96 45'14.9"W 32 57'09.3"N