# RF Considerations for Amateur Radio Data Links

Mike Cheponis, K3MC

Mike@Wireless.Com

# Introduction

We're going to touch on all aspects of RF engineering that you'll have to deal with when you plan your fixed point-to-point data link or your indoor or outdoor mobile to fixed link, primarily above 900MHz.

# What We Will Talk About

- Paths
- Antennas
- Cable
- Connectors
- Measurements
- Site Considerations

# Quick Math Review

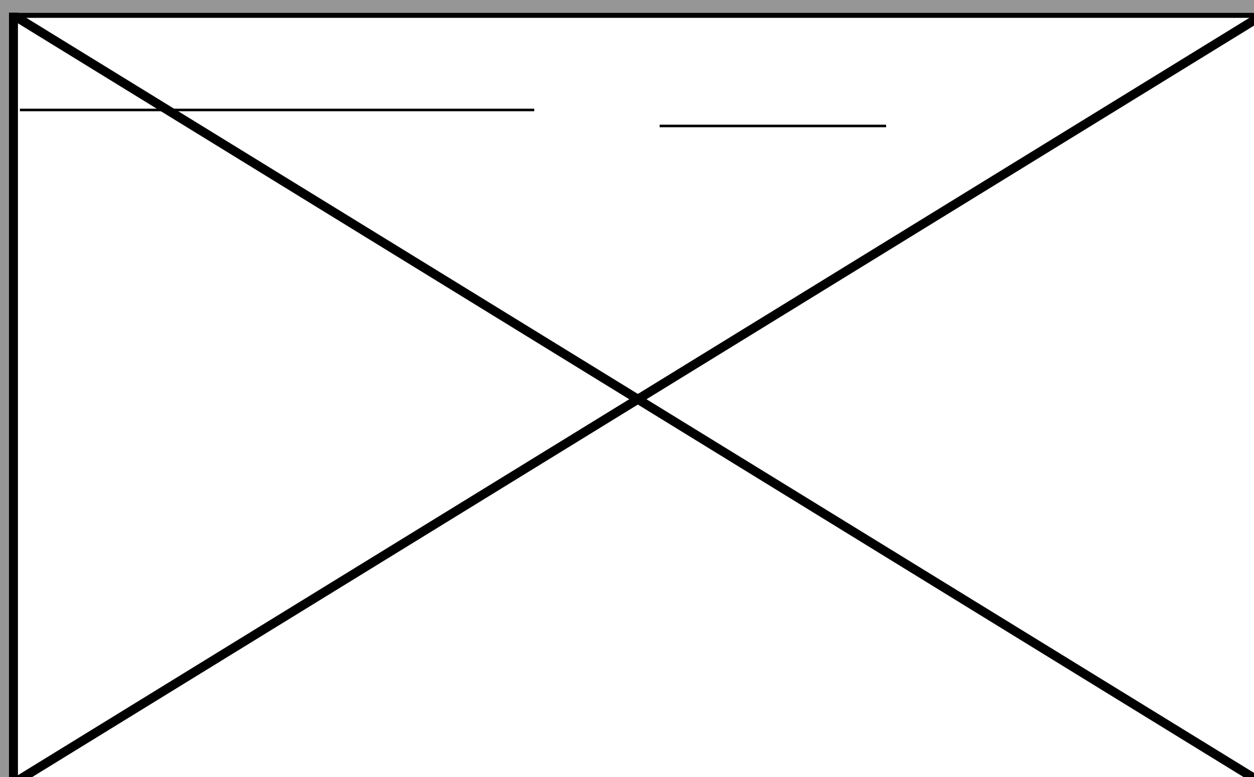
Exponential Notation

Logarithms

Powers

Notation

# Frequency vs Wavelength



# Free Space Propagation Model

- Also called the Friis free-space model
- Useful for line-of-sight Microwave links
- Satellite Links
- Mobile/Portable to Base (unobstructed)

# Equations

$$P_r(d) = \frac{P_t\, G_t\, G_r\, \hat{I}^2}{(4\pi)^2\, d^2\, L}$$

Where Pt is the Transmitter power

Pr(d) is the received power

Gt, Gr are Transmitter and Receiver Power Gain

d is the Tx-Rx separation in meters

L Is the system loss factor not related to propagation (>=1)

Î is wavelength in meters

# Gain of an antenna

This is related to the effective Aperture, A:

G = 4 pi $A_e$ / lambda^2

Ae is the *effective aperture,* related to the physical size of the antenna, and lambda is related to the carrier frequency by:

lambda=c/f = 2pi c /omega sub c

# More Definitions

F is frequency in Hz, omega sub c is the carrier frequency in radians per second, c is the speed of light in meters /second.

Psubt and Psub r must be in the same units, Gt and Gr are dimensionless.

L is usually due to transmission line losses, filter losses, antenna losses, etc. L=1 means no loss.

# EIRP and ERP

$EIRP = P_t\ G_t$

This is the maximum radiated power from a transmitter in the direction of the maximum gain of the antenna, compared with an isotropic radiator.

ERP is often used. It compares the maximum radiated power to a half-wave dipole. It will be 2.15 dB smaller than EIRP.

Antenna gains are in dBd or dBi

# Path Loss

PL(db) = 10 log Pt/Pr =

-10 log [Gt Gr lambda^2/(4pi)^2 d^2]

Note, for Friis model, it predicts Pr only if d is in the Far Field

# What is the Far Field?

Also know as the Fraunhofer region, give by

dsubf=2 D^2/lambda where D is the physically largest linear dimension of the antenna.

Also, dsubf >> D and dsubf >> lambda.

# An Example

What is the far field for antenna with a maximum dimension of 1 meter and operates at 900 MHz?

Lambda = c/f = 3e8 m/s / 900e6 Hz

so dsubf = 2*(1)^2 / .33 = 6 m

# Another Example

What is the far field distance for an antenna with a maximum distance of 1.5 inches at 5800 MHz?

1.5 inches * 1 meter/39.37 inches

Lambda=3e8m / 5.8e9 Hz= .0517m

2 * (3.81e-2)^2/.0517= .056m=2.2”

# However...

If dsubf = 5.6 cm and

D = 3.8 cm and

lambda = 5.17 cm THEN since

dsub>>D and dsubf>>lambda,

choose dsubf to be 5 to 10 x.

E.G. use 1 meter for low-gain antennas in .9 to 2.4 GHz region

# For Some Perspective

What's the far field for your KT34A on 20 meters?

D=10m, lambda=20m so

dsubf=2*(10)^2/20=10m

right?

# Example, more

In free space, the Power Flux Density Psubd (W/m^2) is:

Psubd = EIRP/(4pi*d^2) =

Psubt Gsubt/(4pi*d^2) = E^2/Rsubfs = E^2/fi W/M^2

fi = 120*pi ohms = 377 ohms so

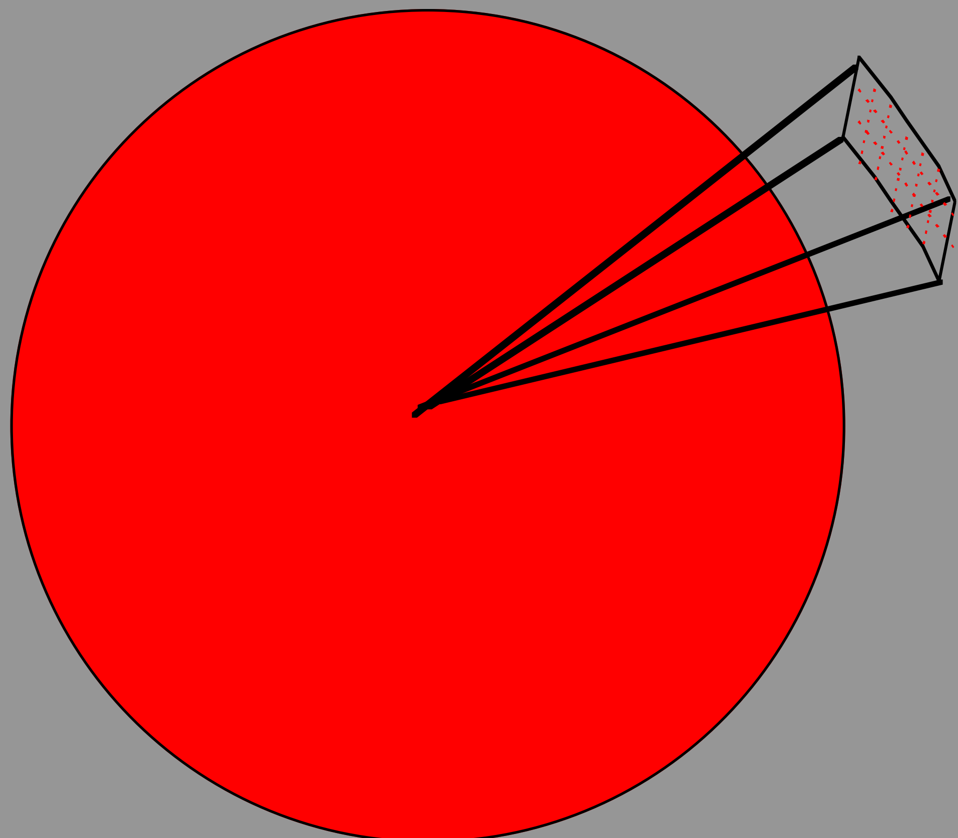
Psubd = mag(E)^2/377 W/M^2

# More, Power Flux Density

Mag(E) is the magnitude of the radiating portion of the electric field in the far field.

You can of Psubd as the EIRP divided by the surface area of a sphere with radius d

# A picture



- 1m x 1m
- Center is Pt Gt

# An example

If a receiver is 10 km away from a 50 watt transmitter on 900 MHz,

Gt=1 and Gr=2, what is the power at the 50 ohm receiver?

Pt = 50W, fsubc=900 MHz, Gt=1,

Gr=2, 50 ohms

# Example, Continued

Pr(d) = 10log(Pt Gt Gr lambda^2 over (4pi)^2 d^2) so:

10log(50 x 1 x 2 x (1/3)^2)) over (4pi)^2 x 10000^2) = -91.5 dBW or -61.5 dBm

# What is the received E-field?

Pd=mag(E)^2/377 ohms W/m^2 so

|E| = sqrt(Pr(d) x 120pi / Ae) =

sqrt(Pr(d) x 120pi/(Gr lambda^2/4pi))=

sqrt(7e-10 x 120pi/(2 x 0.33^2/4pi)) = 3.9 mv/meter

# What is the voltage at the receiver input?

First, if V is the rms voltage at the input of the receiver, and Rant is the resistance of the receiver antenna, then the received power =

Pr = [V/2 / Rant]^2 = V^2/4Rant

so V=sqrt(Pr x 4Rant)=

sqrt(7e-10 x 4 x 50) = 374 uvolts

# Diffraction

# Fresnel Zone Geometry

# Knife-edge Diffraction Model

# Multiple Knife-edge Diffraction

# Log-distance Path Loss Model

# Log-Normal Shadowing

# Longley-Rice Model

# Durkin's Model

# Okumura Model

- Most widely used, good from 150 MHz through 2.5 GHz. Distances from 1km to 100km
- Base Station heights from 30m to 1000m

# Hata Model

Empirical formulation of the path loss data provided by Okumura, and is valid from 150 to 1500 MHz.

# Walfisch and Bertoni Model

# Some notes about indoor propagation

- Typically 3rd or 4th power
- Floor Attenuation: 13 dB, 18 dB, 24 dB, 27 dB (1-4 floors)
- Concrete block wall 13-20 dB
- small metal pole, 6” 3 dB

# Ericsson Multiple Breakpoint Model

# Considerations for Mobile Stations

# Path Measurement

# Direct RF Pulse

# Spread Spectrum Sliding Correlator

# Antenna Basic Types

isotropic, dipole, yagi, corner, loop, dish, patch

# External Filters

# Gain

# HAAT - how high is high enough?

# Feedline

# Attenuation

# Connectors

# Couplers & Inter-series Adapters

Avoid if at all possible!

# Weatherproofing

Silicone RTV

Weather Strip

Enclosures

# Transient Supression

EM fields that induce voltages in primary and secondary power circuits and antennas

Use of Varisistors

# Lightening

Direct Strikes inject high currents by

- Flowing through an R to ground
- Flowing through surge Z to the primary circuit

# Basic Equipment

Detector

Voltmeter

Attenuators

Signal Sources

Frequency Counter

Spectrum Analyzer

# detector

Crystal detectors are square law with impedance near 200 ohms

Frequency-selective detectors,e.g. the common superhet with S meter

# power meter

Older power meters are available for little cost.

# calibrated attenuators

This is certain to be one of the most useful investments!

- N type
- SMA type
- BNC type

# signal generator

Or simple signal sources

- Harmonics of a generator
- SRD multipliers & filters

# spectrum analyzer

EG Hp 851/8551 is 20 years old but you can often buy it for $500 to $1500 in working condition.

# network analyzer

This can give you “R + jX”

And excellent tool, if you can afford it!

# Directional Couplers

Cheap and very useful for tapping off to spectrum analyzer or frequency counter

# Bias Tees

Power devices remotely

Commonly preamps

# Software requirements

# Ping

Adjustable packet length

Remote echo server

# FTP

Large files provide indications of

- many fixed-size packets
- total link throughput

(Tends to wash out overhead variation)

# Special-Purpose s/w

Send-only

Receive-only

Stats-gathering only

# Overview: Living within the ISM bands

Interference from others

Interference to others

Interference Mitigation

# Interference Potential

# Link Reliability

BLER

Packet Stats

Conversion to BER

# Rules for Hams, unlicensed

15.249 and 15.247

750 microwatts or 1 watt + gain antenna

# Prognosis for the future

We've only just begun!

I expect we'll see:

- Point to point running at Gb/s
- Mobile running at several Mb/s
- handheld MPEG ATV "HTs"