Communication Range Analysis

Using Interactive MATLAB Application Program

John Conneely
Avionics System Integration
Sikorsky Aircraft Corporation
June 15, 2006
Analysis of the communication radio link between a helicopter and a ground station
Objective

- Determine the maximum distance (range) for clear 2-way communication, defined such that the signal-to-noise ratio (SNR) is at least 10 dB
- Alternatively determine the gain margin at the required range, which is the amount of gain above the minimum required for clear 2-way communication at that distance
Communication Range Analysis
System Description

Helicopter

- 3-D surface model developed in CAD tool
- Wire frame mesh generated from model
Communication Range Analysis

System Description

Antenna

- Gain, directivity, efficiency, VSWR
- Function of frequency and/or azimuth & elevation
- Radiation pattern is distorted by helicopter structure
The Fris transmission formula provides the received signal power in free space:

\[
P_R = P_T G_T G_R \left( \frac{\lambda}{4\pi r} \right)^2 \left[ 1 - \left( \frac{S_T - 1}{S_T + 1} \right)^2 \right] \left[ 1 - \left( \frac{S_R - 1}{S_R + 1} \right)^2 \right] \text{ (watts)}
\]

Free space calculation ignores the effect of the environment. Replace with ITM propagation model attenuation to incorporate the effect of terrain, climate, etc.

- **\( G_T \)** = transmitting antenna gain (in the direction of the receive antenna)
- **\( P_T \)** = Transmit Power
- **\( r \)** (meters) = separation distance
- **\( G_R \)** = receiving antenna gain (in the direction of the transmit antenna)
- **\( P_R \)** = Received Power (Receiver Sensitivity)
- **\( \lambda \)** = wavelength
- **\( S_T \)** = antenna reflection coefficient at transmitter
- **\( S_R \)** = antenna reflection coefficient at receiver
- **\( 4\pi r \)** = path length
- **\( \frac{\lambda}{4\pi r} \)** = free space attenuation factor
- **\( \left( \frac{S_T - 1}{S_T + 1} \right)^2 \)** = transmission loss due to impedance mismatches at transmitter
- **\( \left( \frac{S_R - 1}{S_R + 1} \right)^2 \)** = transmission loss due to impedance mismatches at receiver
Description

• User-interactive software tool for the analysis of helicopter communication system

Functionality

• Incorporates pattern data from antenna modeling program
• Incorporates radio and antenna manufacturer’s data
• Computes efficiency and gain of antenna on helicopter
• Computes RF attenuation, communication range, etc
• Provides 2-D and 3-D plots of gain, attenuation, range, etc
• Provides interactive and batch mode processing
• Generates an HTML report file that includes text and plots
Communication Range Analysis
MATLAB Application Program

MATLAB Application Program

Command Line Input
>> load radios
>> setup comm
>> compute prop
>> ...

Script File

External File Input
User Interface
Output Plot

Radiation Pattern
Fr Az El Dir
30 10 20 1.42
...

Excel Radio Data
N P T B...

Excel Antenna Data
N P T B...

External File Input
User Interface
Output Plot
User Interfaces
• Graphical user interface
• Command line interpreter
  ➢ Enter command followed by object and one or more parameters
  ➢ Command is interpreted as a call to object’s method function
• Script file

External Input Files
• Radiation pattern data
  ➢ Directivity, output of antenna modeling program
• Radio manufacturer’s data
  ➢ Transmit power, receiver sensitivity
• Antenna manufacturer’s data
  ➢ Gain, VSWR
**Software Design**

- **Graphical User Interface**
  > Developed using MATLAB GUIDE
- **Command Line Interpreter**
  > Shell around MATLAB interpreter
- **Object-Oriented Code**
  > Each major component is a MATLAB object
  > Each object has data and methods that define actions
  > Provides data encapsulation, enhances code clarity
- **Fortran MEX API**
  > Interface between MATLAB and Fortran code
  > Incorporates RF propagation algorithms
Communication Range Analysis

• Helicopter S-92
  • Radio UHF AM
    - TX Power 10W
  • Antenna
    - Gain –5, 0, +5 dBi
  • Altitudes
    - 100 to 10,000 ft

• Ground Station
  • Radio UHF AM
    - RX Sens –99 dBm
  • Antenna
    - Gain 5 dBi
  • Height 6 ft

• Environment
  • Sea water
  • Maritime climate

• Frequency
  • 300 MHz
Gain Margin Analysis

- **Helicopter** S-92
- **Radio** ARC-210
- **Antenna** 12-190-6
- **Environments**
  - Sea water (shown)
  - Level soil
  - Rolling hills 30 ft
  - Rolling hills 100 ft
- **Frequency Bands**
  - 30-88 MHz
  - 118-156 MHz
  - 156-174 MHz
  - 225-400 MHz
- **Altitudes**
  - 500 ft
  - 1500 ft
  - 5000 ft
  - 7500 ft

![Gain Margin: Propagation Over Water](image)
Conclusion

• Communication range analysis
  ➢ Range increases with aircraft altitude
  ➢ Range increases with antenna gain

• Gain margin analysis
  ➢ Gain margin is higher for lower frequencies (VHF band)
  ➢ Lower gain antennas and/or more cable loss could be tolerated in VHF band

• Tool usefulness
  ➢ Allows user to see the individual and combined effects of several competing factors
  ➢ Improves workflow and efficiency in system analysis
  ➢ Candidate for inclusion into Sikorsky standard work process