Communication Range Analysis

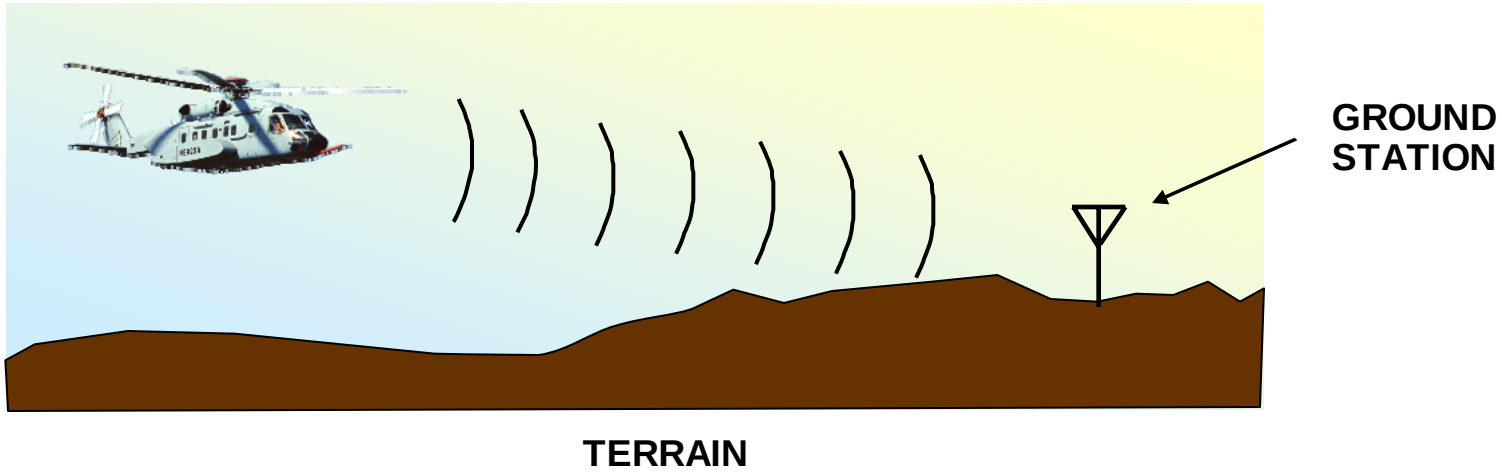
Using Interactive MATLAB Application Program

John Conneely
Avionics System Integration
Sikorsky Aircraft Corporation
June 15, 2006

Communication Range Analysis

Problem Definition

Analysis of the communication radio link between a helicopter and a ground station



Communication Range Analysis

Problem Definition

Objective

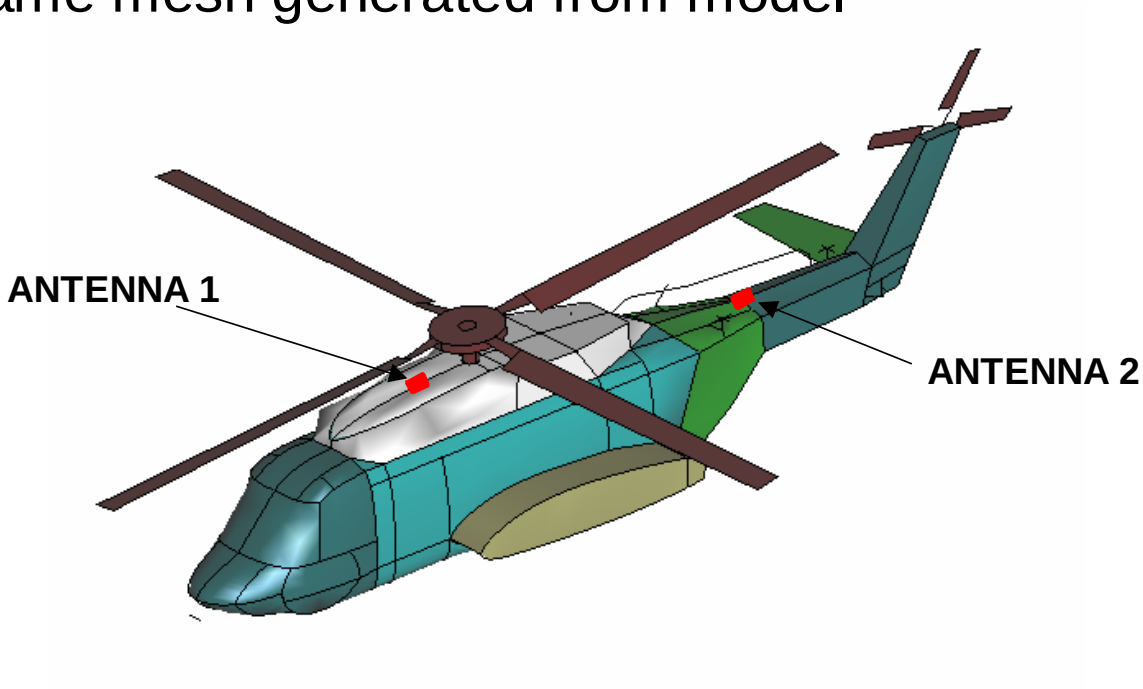
- Determine the maximum distance (**range**) for clear 2-way communication, defined such that the signal-to-noise ratio (SNR) is at least 10 dB
- Alternatively determine the **gain margin** at the required range, which is the amount of gain above the minimum required for clear 2-way communication at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

Communication Range Analysis

System Description

Helicopter

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



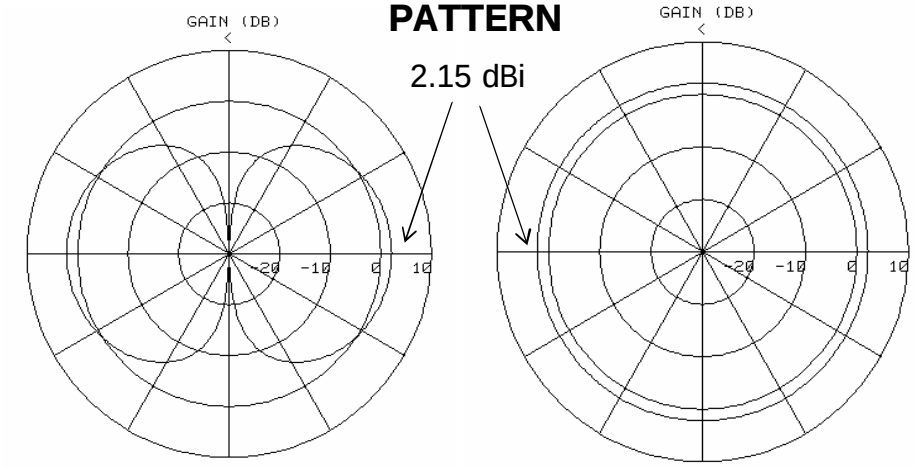
Communication Range Analysis

System Description

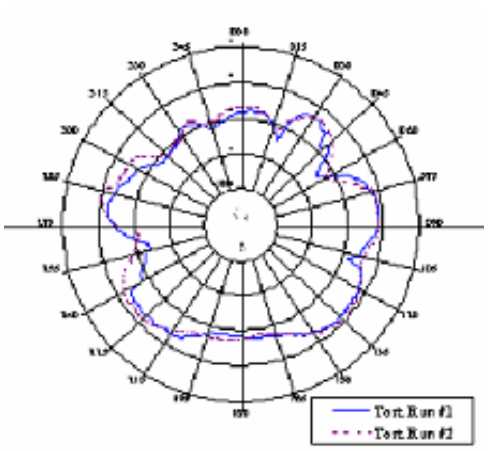
Antenna

- Gain, directivity, efficiency, VSWR
- Function of frequency and/or azimuth & elevation
- Radiation pattern is distorted by helicopter structure

Half-Wave Dipole PATTERN

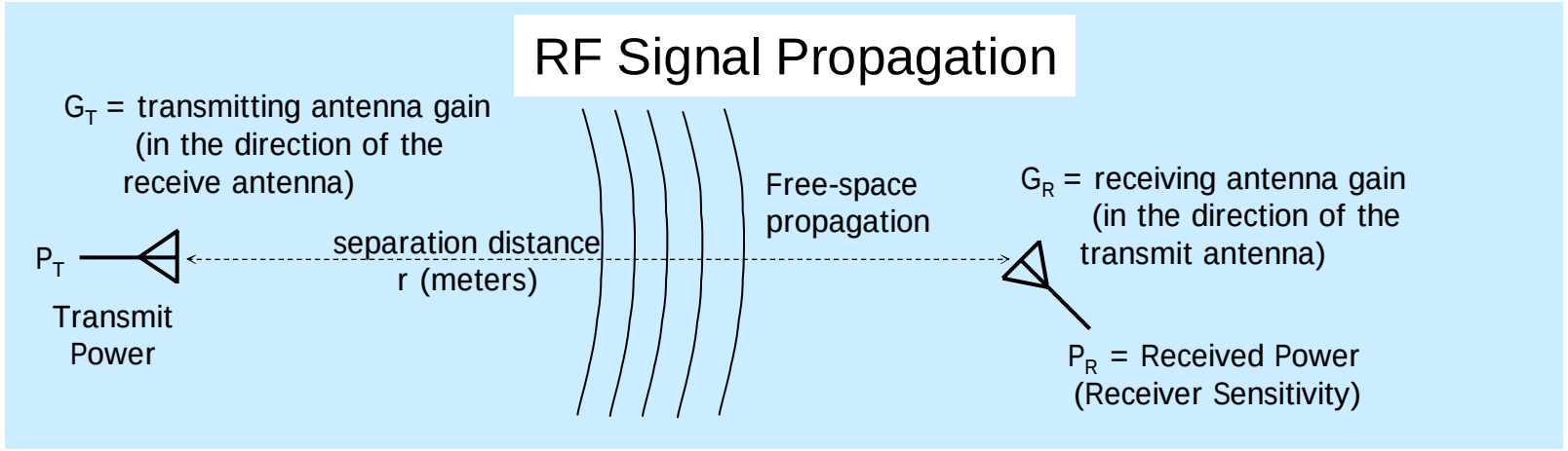


DISTORTION



Communication Range Analysis

System Description



The Fris transmission formula provides the received signal power in free space:

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

Free space loss

Loss due to impedance mismatches at transmitter and receiver

Free space calculation ignores the effect of the environment

Replace with **ITM propagation model** attenuation to incorporate the effect of terrain, climate, etc

Communication Range Analysis
MATLAB Application Program

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

Command Line Input

```
>> load radios
>> setup comm
>> compute prop
>> ...
```

Script File

Radiation Pattern

Fr	Az	El	Dir
30	10	20	1.42
...			

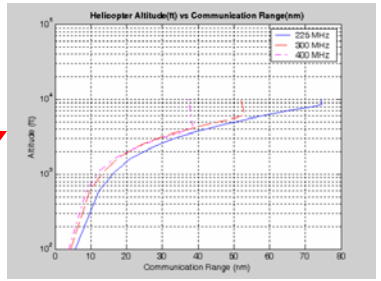
Excel Radio Data

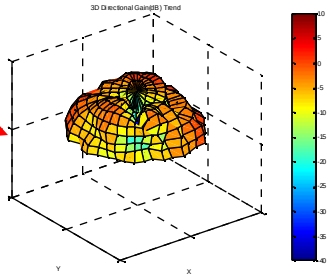
N	P	T	B	...	

Excel Antenna Data

N	P	T	B	...	

MATLAB Application Program





External File Input

User Interface

Output Plot

Communication Range Analysis
MATLAB Application Program

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

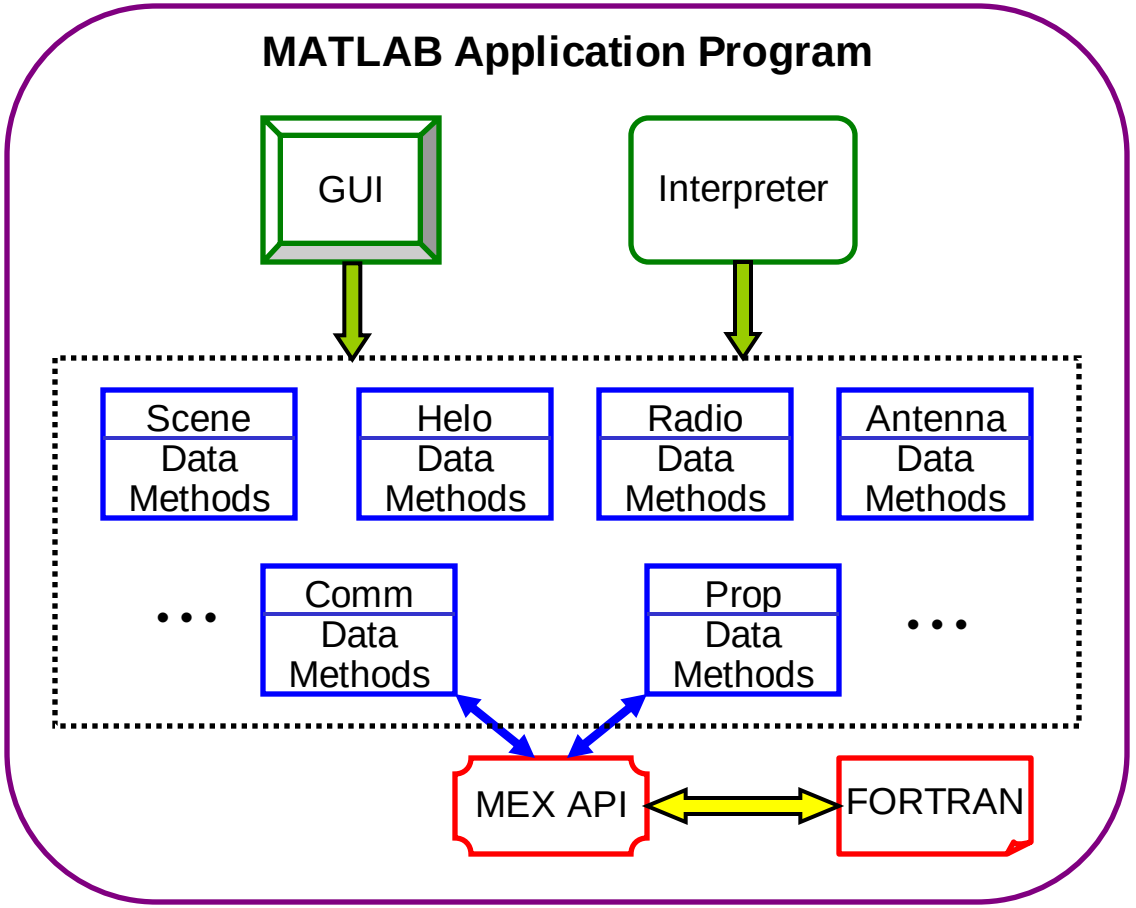
- Radiation pattern data
  - Directivity, output of antenna modeling program
- Radio manufacturer's data
  - Transmit power, receiver sensitivity
- Antenna manufacturer's data
  - Gain, VSWR

Communication Range Analysis

MATLAB Application Program

Software Design

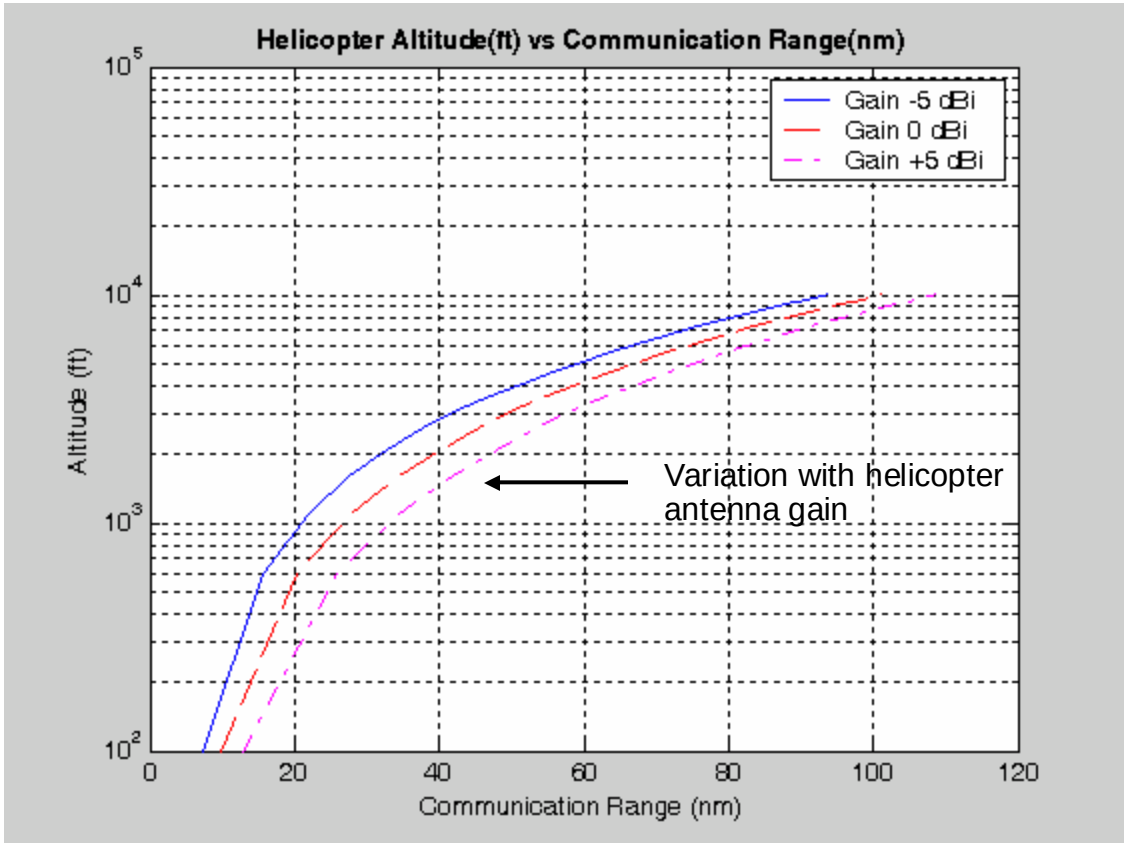
- **Graphical User Interface**
  - > Developed using MATLAB GUIDE
- **Command Line Interpreter**
  - > Shell around MATLAB interpreter
- **Object-Oriented Code**
  - > Each major component is a MATLAB object
  - > Each object has data and methods that define actions
  - > Provides data encapsulation,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



Communication Range Analysis
Problem Solution

Communication Range Analysis

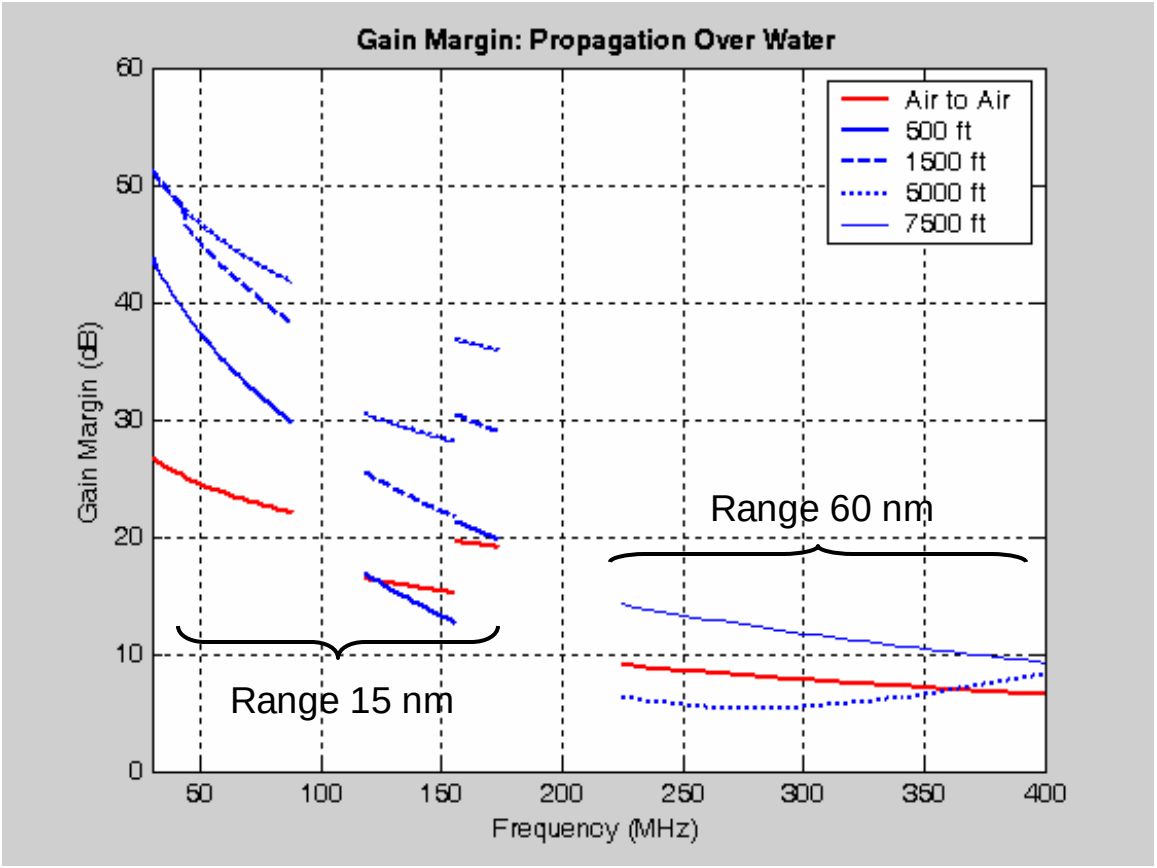
- **Helicopter** S-92
  - **Radio** UHF AM
    - TX Power 10W
  - **Antenna**
    - Gain –5, 0, +5 dBi
  - **Altitudes**
    - 100 to 10,000 ft
- **Ground Station**
  - **Radio** UHF AM
    - RX Sens –99 dBm
  - **Antenna**
    - Gain 5 dBi
  - **Height** 6 ft
- **Environment**
  - Sea water
  - Maritime climate
- **Frequency**
  - 300 MHz



Communication Range Analysis
Problem Solution

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



Communication Range Analysis
Problem Solution

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