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APPROVALS		DATE
DRAWN	Robert DeLong	4/17/98
CHECKED	Steve Elliott	4/17/98
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REVISIONS

REV	DESCRIPTION	DATE	APPROVED
A	**INITIAL RELEASE**	4/24/98	S. ELLIOTT
B	REDRAWN PER DCN W294 ADDED CALCULATION FOR WAVE LENGTH		

NEXT ASSEMBLY	FINAL ASSEMBLY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
±	.XX ±	±
	.XXX ±	

DRAWING TITLE

ESTIMATION OF RADIO TRANSMISSION RANGE

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SCALE

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APPLICATION NOTE WAN-001

ESTIMATION OF RADIO TRANSMISSION RANGE

The purpose of this application note is to provide system planners insight into estimating transmission range of an airborne communication system to a ground station.

Accurate calculation of radio transmission range in a communication system is difficult. In addition to the performance of the system components, environmental factors such as terrain, moisture, etc., can greatly affect transmission range. Radio propagation involves many mechanisms which factor into the received signal strength, including free space transmission, reflection, refraction, scattering, and diffraction. For the purposes of this application note, it is assumed that the primary mode of propagation for aircraft communication is free space transmission, which for all practical purposes will be proven to be limited to line-of-sight transmission.

Transmission loss for free space propagation is determined by the following formula:

$$L_T = L_b - G_T - G_R \text{ (dB)} \qquad \text{Eq. 1}$$

where:

$$L_b = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \text{ (dB)} \qquad \text{Eq. 2}$$

G_R = Receiver Antenna Gain (dBi)

G_T = Transmitter Antenna Gain (dBi)

d = distance in meters

λ = wavelength in meters = $3x10^8 \div$ Frequency (Hz)

For a given loss, the associated distance can be found by solving Equation 2 for distance:

$$d = \frac{\lambda}{4\pi} 10^{\frac{L_b}{20}} \text{ meters} \qquad \text{Eq. 3}$$

For a given system, the maximum transmission loss is:

$$L_{T\ Max} = P_{TX} - P_{Sen} \ \text{(dB)} \qquad \text{Eq. 4}$$

where:

$$P_{TX} = \text{Transmitter Power (dBm)}$$

and

$$P_{Sen} = \text{Receiver Sensitivity (dBm)}$$

Combining Equations 1, 3 and 4 yields a maximum distance:

$$d = \frac{\lambda}{4\pi} 10^{\frac{\left(P_{TX} - P_{Sen} + G_T + G_R\right)}{20}} \ \text{meters} \qquad \text{Eq. 5}$$

For example, the maximum free space transmission range between two RT-5000 systems operating at 31.480 MHz, FM, with an AT-550 antenna is as follows:

$$P_{Sen} = -111 \ \text{(dBm)}$$

$$P_{TX} = +40 \ \text{(dBm)}$$

$$G_R = G_T = -14 \ \text{(dBi) @ 31.48 MHz}$$

$$\lambda = 9.53 \ \text{meters @ 31.48 MHz}$$

Max. transmission distance = 1,071 km @ 31.48 MHz

It is will be shown that at 1,071 km, the aircraft will not be in view due to the curvature of the earth. Communication beyond the curvature of the earth can be obtained by other means of propagation, such as ionospheric reflection or diffraction from the earth. These modes of propagation strongly depend on frequency and environmental conditions. The free space transmission distances for select frequencies for a RT-5000 system are listed in the following table:

Frequency (MHz)	Antenna Gain (dBi)	Distance (km)
30	-14	1,071
88	-6	2,418
174	0	4,868
500	0	1,694
960	0	882

Table 1. Free space propagation for two RT-5000s with AT-550 antennas.

Frequency (MHz)	Antenna Gain (dBi)	Distance (km)
31.48	-21	214
88	-12	1,697
174	-3	2,440
500	0	1,694
960	0	882

Table 2. Free space propagation for two RT-5000s with AT-150 antennas.

The line of sight distance on the smooth earth is a function of aircraft height and can be calculated as follows:

$$d = \sqrt{\left(h + R_{earth}\right)^2 - R_{earth}^2} \quad \text{(meters)} \qquad \text{Eq. 6}$$

Where:

h = Height above the earth (meters)

R_{earth} = Radius of the earth = 6,378 km

The line-of-sight distances from an aircraft to a ground station for various heights are listed in the following table:

Distance above earth (feet)	Line-of-Sight (km)	Line-of-Sight (miles)
1,000	62	41
2,000	88	58
3,000	108	71
5,000	139	91
10,000	197	129

Table 3. Line-of-sight distance to the horizon as a function of aircraft height.

Conclusion:

Line-of-sight distance is a good approximation for radio transmission range for an aircraft. At lower radio frequencies, diffraction by the earth may extend this range, but the effects are dependent on the terrain and environment. Formulas for estimating diffraction are not readably solvable except by numerical approximation. Tables for estimating diffraction effects may be found in the literature.

