COMMUNICATIONS RANGE OF AVIATION BAND BASE STATIONS

This application note was written with the assumption that the reader is familiar with both radio terms and aviation terms. All references to measurement or derived data refer to the aviation VHF communications band of 118 to 137MHz using DSB-AM. Other bands and modulation could result in divergent measurement data.

There are wide variations in the distances obtained for ground-air communications. Under some conditions, the range may be only 10-15 miles; for other conditions the range may exceed 200 miles. In planning new installations, or evaluating existing ones, the following guidelines will help estimate what is "par" for different situations.

The factors listed below affect communications range. For some of these, the characteristics of four pieces of equipment are involved—two receivers and two transmitters, one of each at the ground station and in the aircraft.

Aircraft altitude
Base station antenna height
Receiver sensitivity
Transmitter power
Antenna type, coax type and length
Terrain details, especially as to hills, mountains, but including soil type, snow coverage, etc.

For the discussions which follow, the assumption is made that both receivers produce clear readable audio outputs for signals at their antenna inputs as low as 2 micro volts, with 80% peak modulation. If either receiver is less sensitive than this, or is more heavily squelched, the ranges given below must be reduced.

It is also assumed that appropriate antennas, coaxial cables and connectors are used at both stations. For the ground station this means a vertically polarized 1/4 wavelength ground plane antenna, connected to the radio via RG-58C/U coax or equal (for runs less than 50 ft.) or RG-8/U coax or equal (for runs of 50 ft. to 150 ft.) For longer cable lengths, special (and expensive) very low loss coaxial cable must be used. If the antenna is of the narrow band type, it should be "tuned" for the frequency in use; if it is a broadband antenna, the channel frequency must fall within its bandwidth. The antenna standing wave ratio (VSWR or SWR) should not exceed 1.5 for the ground station or 2.0 for the airborne station. The airborne antenna should be one of the standard widely used VHF aircraft antennas.

A gain antenna may be used at the ground station to increase communications range. Some gain antennas may produce "dead spots" due to lobes in the vertical radiation pattern. An antenna having 6 dB of gain can increase communications range anywhere from 5% to nearly 100%, depending on other factors, as outlined below.

The two most crucial factors in determining communications range are aircraft altitude and terrain. Since VHF radio signal travel along a "line of sight", aircraft that are behind hills or beyond the radio horizon (due to earth curvature) cannot communicate with a ground station, regardless of other favorable conditions.

The next most significant factor is base station antenna height. A high antenna will extend the radio horizon and overcome some shadow effects of nearby buildings, hills, etc. The ground station antenna should be at least 15 feet above the ground—20 feet is better and 30 feet even better still. If roof mounted, the antenna should be mounted near the highest point on the roof. Range figures stated here assume an antenna height of 20 feet above the ground, in gently rolling terrain with low hills. Over flat terrain or water, and for higher antennas, greater range distances may be observed.

A strong readable signal requires a good transmitter carrier level plus good modulation. A good carrier may seem weak if the modulation is poor. Good modulation will make the difference between a readable and unreadable transmission when the carrier strength is marginal. Poor modulation may be due to a bad microphone or poor "microphone technique" by the operator. Aircraft noise-canceling type microphones are highly directional, and are very sensitive to the distance the microphone is held from the mouth and how loudly the operator speaks.

Weather is usually not a major factor for aircraft band VHF communications, but observant radio operators may notice some variations in range that correlate with specific weather conditions. This is also true for variations in snow cover or ground moisture.

The factor of transmitter power was purposely saved for last, because it is often misunderstood and deserves special attention. Sometimes an operator will decide that a range problem could be solved simply by increasing transmitter power, only to find after considerable effort and expense that the improvement is much less than expected.

Increasing base station transmitter power will nearly always increase the communications range, but usually by less than anticipated. For aircraft at altitudes below 8000 feet agl, even a relatively low power transmitter will reach the radio horizon with an acceptable signal level. Thus any increase in range due to higher power results only from the small amount of signal scattering that occurs near the horizon. As a numerical example, for the case of a 2 watt base station talking with an aircraft at 3000 feet agl, increasing power by 5 times, to 10 watts, may increase the range by only 5-10%, or a few miles.

For higher altitude aircraft, the radio horizon is sufficiently far from the ground transmitting antenna that the decreasing signal strength with distance will determine the maximum range instead of the horizon itself. Thus for an aircraft at 15,000 feet agl, a 2 watt base transmitter may give a range of about 90 miles, limited by the signal field strength. Increasing the transmitter power to 10 watts may increase the range to more than 150 miles, the limitation now being the radio horizon.

This does not mean that for low altitude communications there are not some advantages in using a 10 watt transmitter rather than one of 5 watts. The higher power will “cut through interference” better. What really happens in this case is that the stronger the desired signal, the more the receiver’s automatic gain control (AGC) will reduce the receiver sensitivity, so that it responds less to weaker interfering signals.

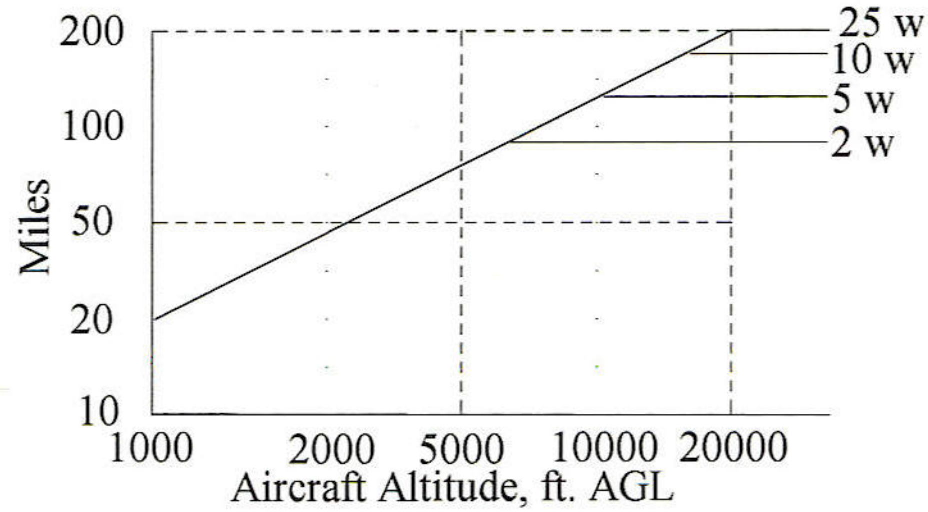
Table 1 shows expected communications range for a 2 watt, 5 watt, 10 watt and 25 watt transmitter, for aircraft altitudes of 2000, 5000 and 10,000 feet agl. For each combination, three ranges are given—a “poor”, an “average”, and an “exceptional” range. The table assumes sensitive receivers in good condition and squelched no greater than 2 micro volts, a good antenna (no gain) 20 ft. agl and relatively flat terrain.

For an existing installation, if ranges are being obtained which from Table 1 are “poor” or below, the performance of all equipment should be measured, including receiver sensitivity, transmitter power and modulation and antenna standing wave ratio. If several different aircraft have the same poor range, the problem is probably in the ground station. If one aircraft has a poor range, but others do not, that aircraft probably has a radio or antenna problem.

Graph 1 shows that for lower altitudes the communication range is “radio horizon limited”, while at higher altitudes it is “signal strength limited”. Thus increasing transmitter power is most effective for high altitude aircraft at relatively great distances from the base station.

	POOR			**AVERAGE**			**EXCELLENT**		
Transmitter power →	**5w**	**10w**	**25w**	**5w**	**10w**	**25w**	**5w**	**10w**	**25w**
AIRCRAFT ALTITUDE ↓									
2,000 ft		**-----20-----**			**-----40-----**			**-----45-----**	
5,000 ft		**-----30-----**			**-----70-----**			**-----80-----**	
10,000 ft		**-----50-----**			**-----110-----**			**-----120-----**	
20,000 ft	**60**	**80**	**100**	**120**	**170**	**200**	**130**	**180**	**220**

Table 1: Communications Ranges—Base Station to Aircraft (miles)



Graph 1: Range (miles) vs. Altitude (feet agl) for Different Transmitter Radiated Power Levels (watts)