Understanding and Specifying Video Downlinks

Introduction

This application note is intended to help the reader get an understanding of the various general types of video downlink systems available. For the sake of brevity, the systems discussed are digital, COFDM (Coded Orthogninal Frequency Division Multiplexing), systems. The same general principles can be applies to analog systems, as well, though these are decreasing rapidly in popularity for a variety of reasons.

It should be noted

- This application note is not written as a puff-piece for MRC products. It is written to give the reader an overview of video downlinks, to help in specifying the right type of equipment the first time, rather than after the wrong equipment has already been procured. The only advertisement is in the closing notes.
- The specifications used to create the tables in this document are fairly generic. They are not intended as detailed equipment specs. Please see MRC sales literature for that information.
- Where prices are quoted, they should be taken as ROM (Rough Order of Magnitude) prices. MRC provides equipment at competitive prices; however, this type of document is not the forum for exposing those prices.

System Overview

Video downlink systems are becoming of ever increasing importance in public safety and law-enforcement applications. Frequently, however, we find that our customers' requirements do not match the specifications, which are issued. This application note will discuss digital video downlink systems and provide guidelines for properly specifying the systems in order to assist the customer in acquiring a system that will meet mission requirements.

Understanding System Gain, Fade Margin, and Range

Two of the most important things take into account when planning a video downlink system are system gain and fade margin, and how hey affect range. They are also, unfortunately, poorly understood.

System Gain is the sum of the transmitter power, and antenna gains, minus any fixed system losses and the receiver's threshold (the point at which the receiver will cease to produce a usable output.

Fade Margin is most easily defined as the difference between the calculated receive carrier level at a given range and the receive systems threshold.

Since microwave energy dissipates at a predictable rate, a range vs. fade margin chart can be made for any proposed video downlink system.

To prepare such a chart the information in Table 1 is needed for the specific equipment being used or specified. These characteristics taken together make up the system gain. For the sake of example, the specifications given are for a typical 2.4 GHz system.

Table 1

Transmitter Power	37 dBm (5 Watts)
Transmitter Antenna Gain	5 dBi
Receiver Antenna Gain	5 dBi
Fixed Losses	2 dB
Receiver Threshold	-87 dBm
System Gain	132 dB

The system gain number remains the same regardless of the distance the transmitter is from the receiver. Fade margin for any point along the path is then calculated by subtracting the "free space attenuation" from the system gain number. This free space attenuation is calculated by using the following formula.

Free space attenuation = 96.6 + 20log F + 20log D

(F = frequency in GHz and D = distance in miles)

By repeating this calculation for multiple values of D, we can create a chart of calculated fade margin vs. range.

Figure 1 below shows a simple range vs. fade margin chart for a 2.4 GHz Omni - Omni video downlink

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system. Note that in this case the fade margin approach is 0 at 30 miles range. Therefore, the system **will fail** at 30 miles. In defining a systems maximum range it is important, however, to understand the difference between the range at which the system will fail, and where the system may fail. Keep in mind that our calculations only take into account the known characteristics and equipment to and free space attenuation. Nowhere in the calculations have we taken into account any additional losses that may be caused by atmospheric conditions, or blockade from natural or man-made obstacles. It is therefore prudent to "back off" the predicted maximum range by some number to estimate a practical operational range. There is no hard and fast engineering rule that determines this. Fixed microwave systems are meticulously calculated to have 99.999% reliability, and generally are engineered to a 40 dB fade margin.

For video downlink systems, an extremely aggressive salesperson would not allow any back off, while an overly conservative engineer might allow 20 dB. MRC typically takes the middle road and backs off the predicted range to the point where we have 10 dB of fade margin. Using this rule, we would call the practical operational range of this system 10 miles, rather than 30.

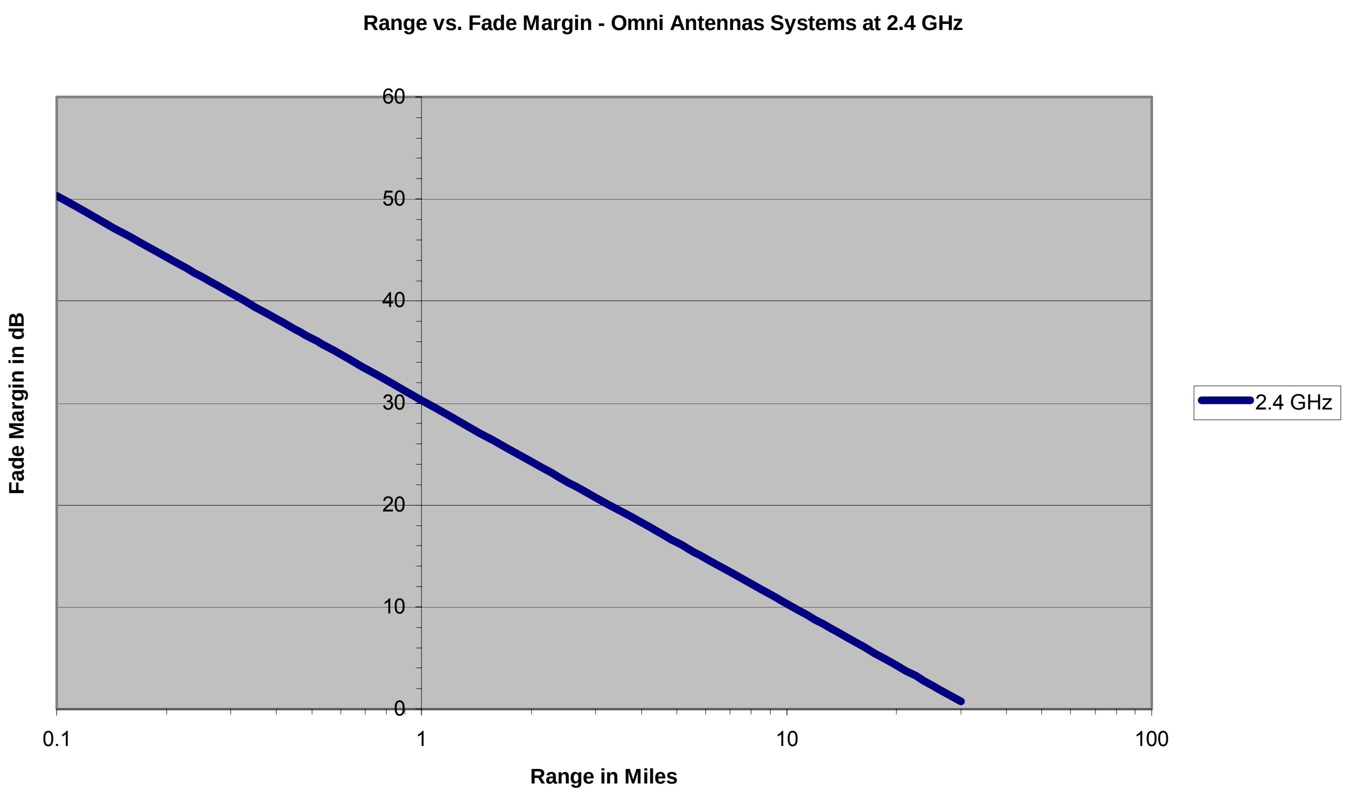

Figure 1

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What range to you need for your mission?

With these explanations of fade margin, system gain, and range out of the way, we can move on to discussing the general characteristics to look for in a system that will meet the mission range requirements you have in mind.

Short-range, tactical system - A short range, tactical system is typically thought of as an omnidirectional antenna on the aircraft, with a corresponding omnidirectional antenna for the receiver. Frequently the receiver is equipped with a built-in video monitor, and speaker or headphone jack. The 2.4 GHz system described in Figure 1 would probably meet those requirements.

Unfortunately, because of frequency congestion and interference from other services it is not always practical to use 2.4 GHz. The other two bands in which law-enforcement can be licensed our 4.9 GHz, and 6.4 GHz. Figure 2 shows a comparison among these three frequency bands. Note that while the 2.4 GHz system has a maximum range of about 30 miles and a practical operational range of about 10 miles the 4.9 GHz and 6.4 GHz systems come in with a maximum range of only about five miles and practical operational ranges of just under two miles.

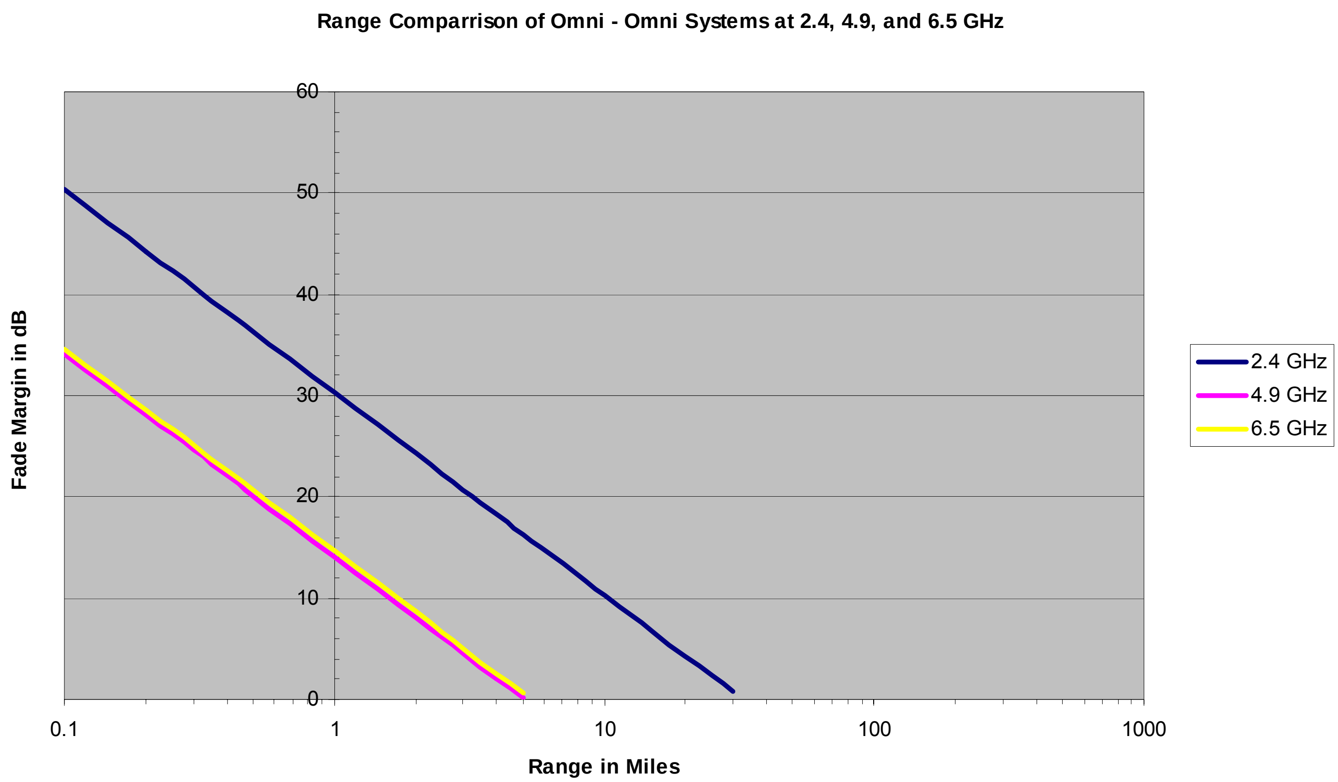

Figure 2

Medium-range, tactical system - A medium-range, tactical system will generally consist of the same equipment to the aircraft, but the ground-based

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system would require a directional antenna to provide some additional gain, and therefore additional system gain. For the purpose of the chart in Figure 3, we have added a 16 dBi MegaHorn antenna. Note that this addition increases the practical operational range of the 2.4 GHz system to about 30 miles, while the 4.9 GHz and 6.4 GHz systems increase to six or seven miles. It should be noted that a MegaHorn antenna like this is a directional device and would need to be manually pointed by an operator at the receive location.

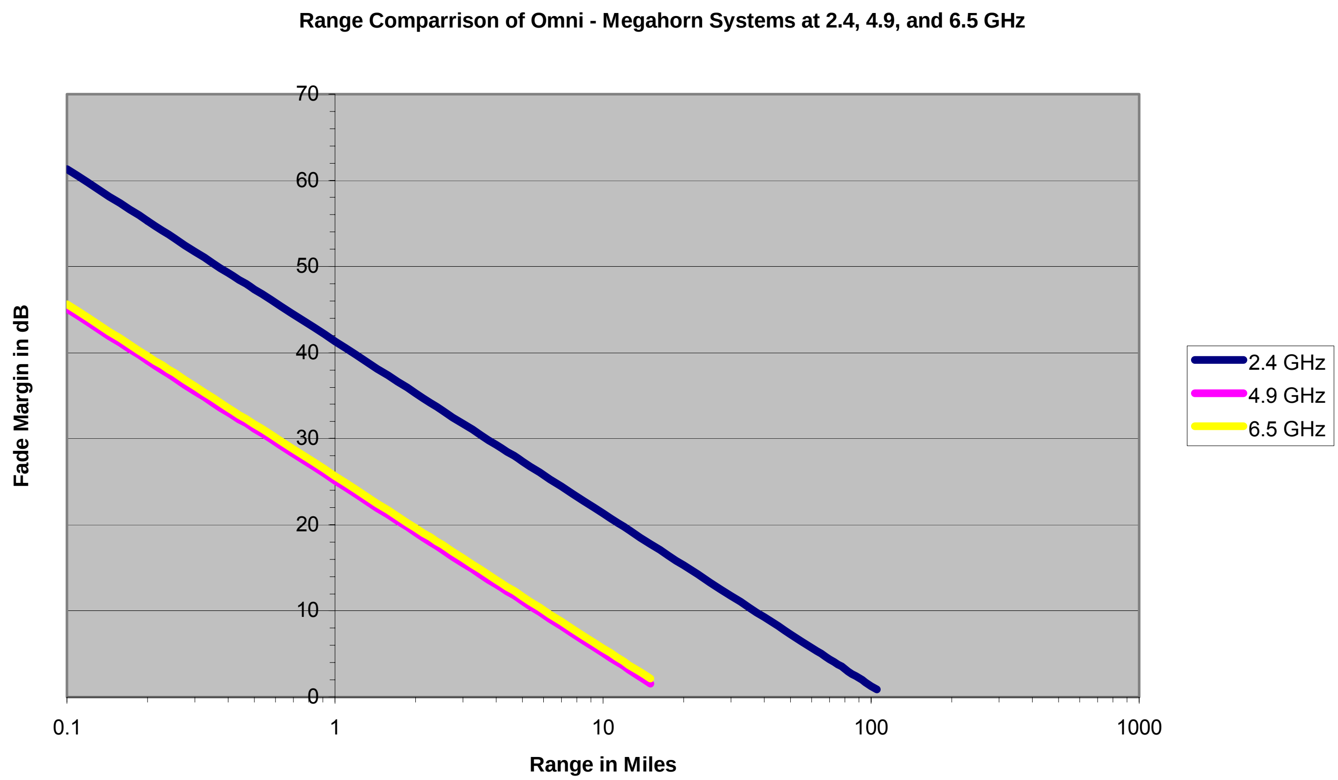

Figure 3

Medium-range, strategic / tactical system – A strategic system is, by definition, an antenna at a fixed location. Although an omnidirectional antenna could be used for this purpose, it is far more common to use a directional antenna, for the additional range and interference reduction it can produce.

The antenna used for this example is an UltraScan. It is steerable, and generally set-up to automatically track the aircraft.

Tactical systems can also be built like this, however, they are comparatively heavy, and are mostly found in mobile-command vehicles.

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You will note that the relationship of the three lines for 2.4, 4.9, and 6.5 GHz changes. This is because reflector-style antennas, like an UltraScan have an increase in gain, as frequency increases.

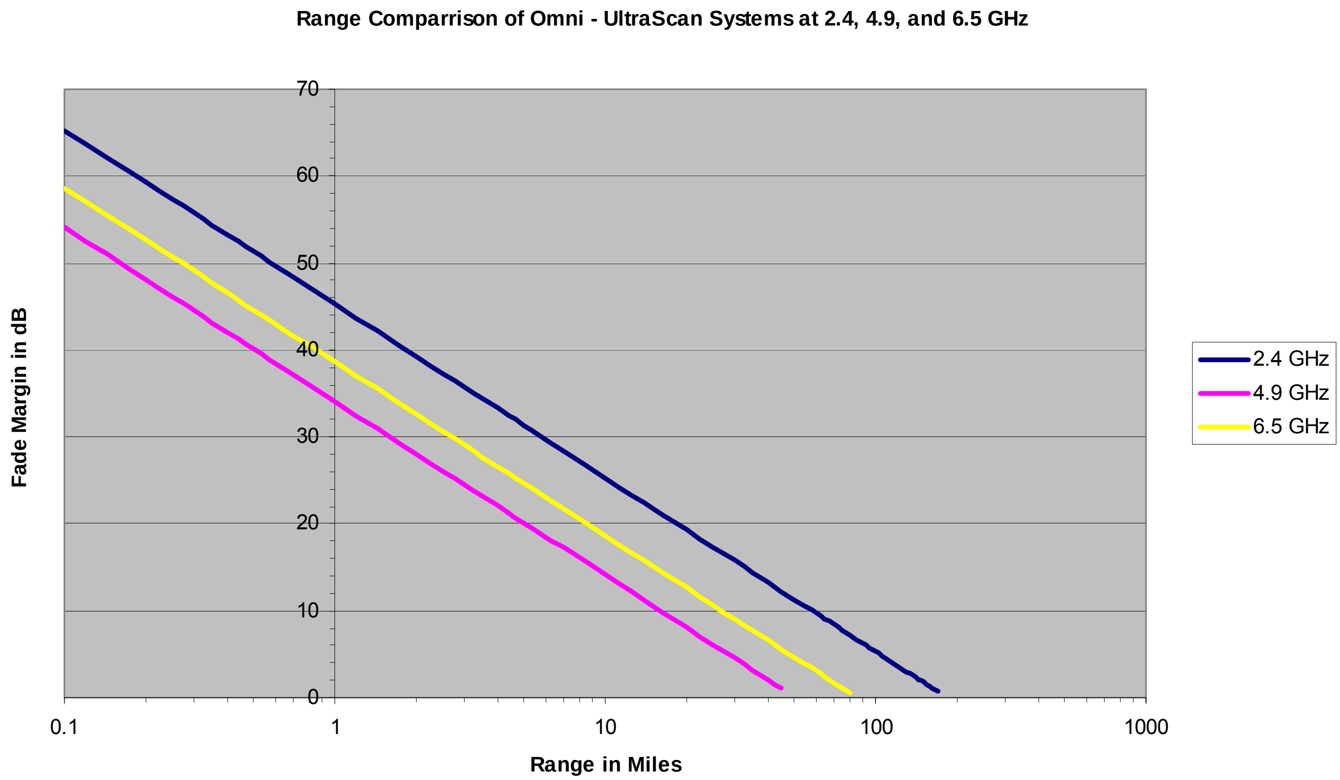

Figure 4

***Long-range, strategic / tactical system* –** Our last range chart, in Figure 5 is for a long-range strategic / tactical system. In this case, we continue to use an UltraScan antenna at the receive site, but change-out the omni on the helicopter for a high-gain steerable antenna pod. Systems in this configuration have gains between 11 and 15 dBi.

Now that we have built up the fade margins so that we are into the long-range category, it's an appropriate time to start discussing the geographic limiting factors that must be considered (radio horizon, and terrain blockage) since geography is most likely the limiting factor on this type of system, rather than system gain.

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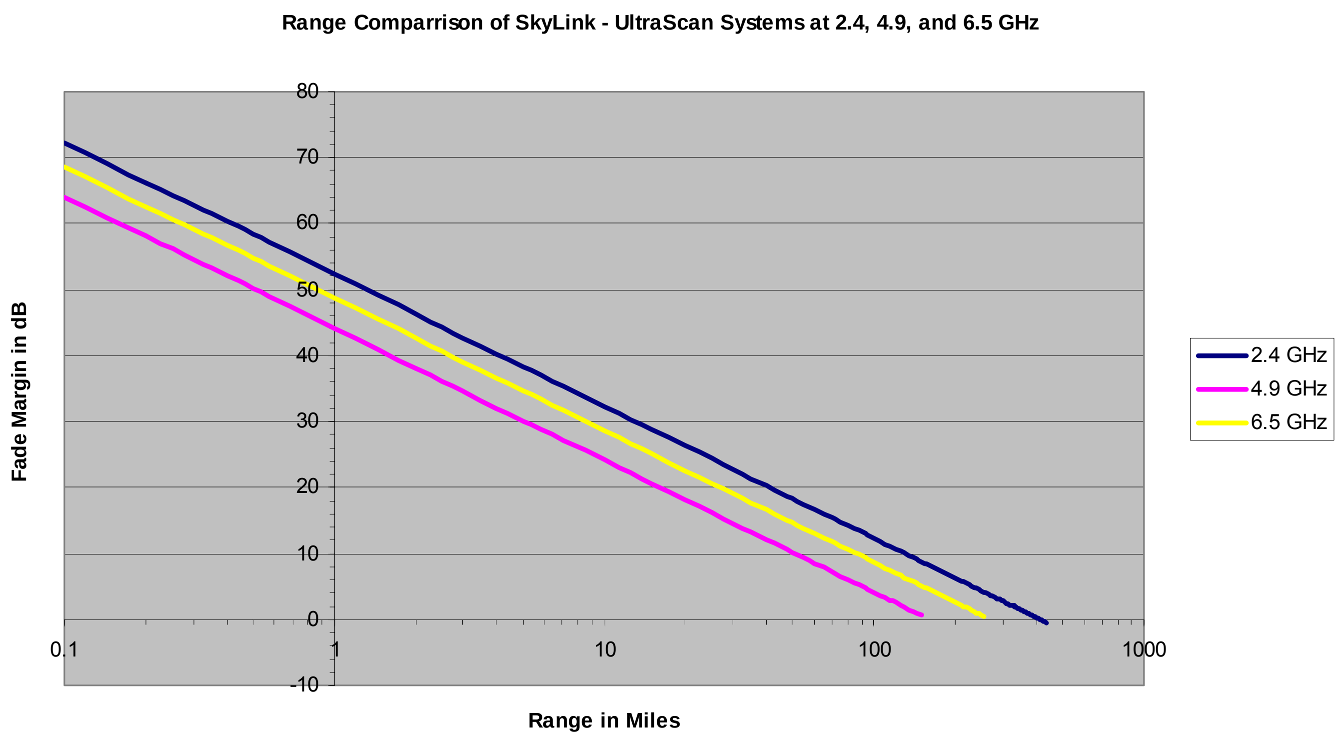

Figure 5

Range Limiting Factors

If one just looks at Figure 8, and takes it at face value, the conclusion would be that the system described is good for over 100 miles. The following factors limit range, however, and must be considered in planning a system.

Radio Horizon

Radio Horizon is determined by the elevation of the transmitter and receiver antennas, the distance between them and the curvature of the earth. For RF purposes we also factor in atmospheric refraction (bending) of the microwave signal. This refraction makes the earth "appear" to have a larger radius than it does. For typical atmospheric conditions this is considered 4/3 earth curvature.

Radio horizon can be calculated using the following formula.

$D = K(\sqrt{2}\ h_r + \sqrt{2}\ h_t)$

Where D is the radio horizon in miles

K = 4/3 or 1.33

h_t = Height of the transmitter in feet

h_r = Height of the receiver in feet

Figure 6 below shows a chart with radio horizon plotted from aircraft flying between 500 and 10,000 feet, transmitting to receivers at 6 feet (tripod mount), 40 feet (atop a pneumatic mast), 250, 500 and 1000 feet (various tower heights) and 6,000 feet (a nearby mountain top).

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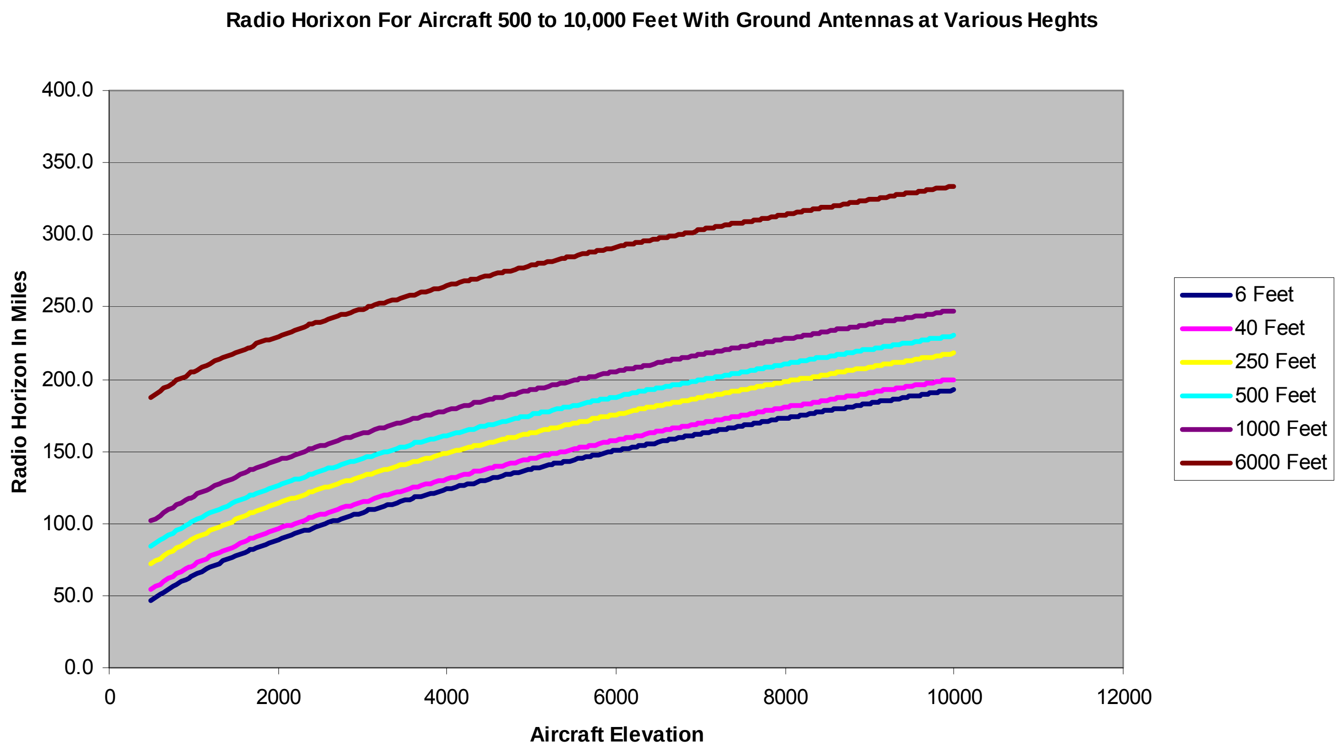

Figure 6

Referring to Figure 6, it is shown that with a 250 foot tower, we would be able to receive from an aircraft flying at 500 feet from a distance of about 80 miles. From a tripod-mounted antenna, however, we could only receive from about 45 miles.

Terrain Blockage

Terrain Blockage is, as one would expect, simply the signal blockage that occurs because of geographic features. When planning a strategic site it is important to select a site that will provide the best coverage, and to do this it is necessary to create an RF coverage map. Although this is recommended for any strategic system planning, its importance is proportional to the terrain in the local area. In a perfectly flat area, RF coverage would be a perfect circle equal to the radio horizon. In areas with hills, or mountains, terrain features distort this perfect circle.

For the sake of illustration, Figure 7 shows a tower in the parking lot at MRC's corporate headquarters, in Billerica Massachusetts. The tower we're proposing is a 100 foot structure. The distortion of our "perfect circle" is caused by the rolling hills associated with this part of New England.

Figure 8 would be an alternate site that we might consider on top of the Prudential tower in Boston. From an engineering standpoint, this would be a much better location for a strategic site, since the coverage is dramatically increased.

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Figure 7

Figure 8

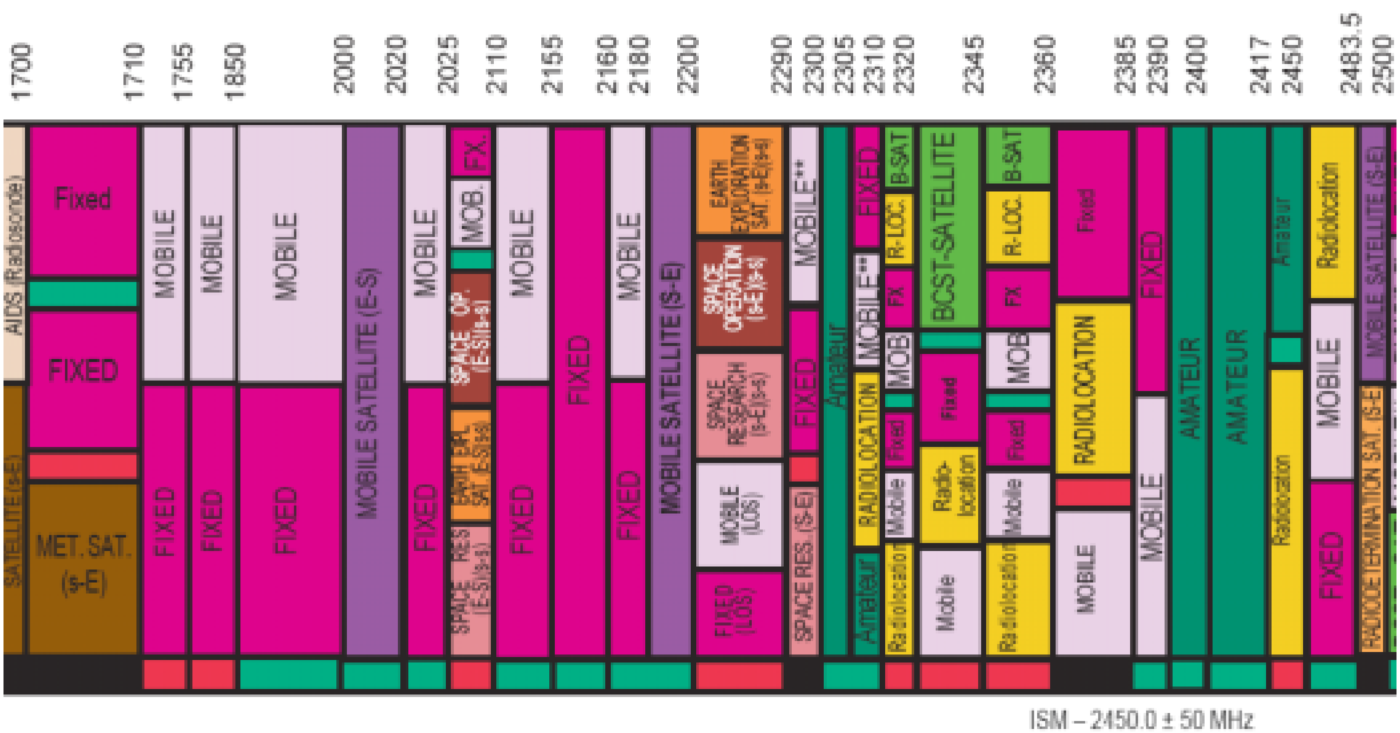

Figure 9

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Interference

The final factor to consider is the potential for RF interference. This may come from other licensed users of the band operating on the same or adjacent channels, from other services, or in the case of the 2.4 GHz band from the sharing of the spectrum with ISM (Industrial Scientific and Medical) users.

Figure 9 is a taken from the NTIA's US Frequency Allocation Chart. The chart in it's entirety can be downloaded from their website at http://www.ntia.doc.gov.

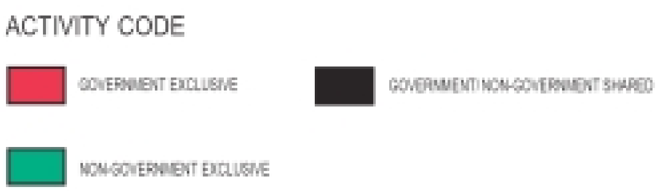

Figure 10

In all bands available to Public Safety there is potential for interference. The questions are who are the potential interferers, and how likely are they to affect proper operation of your system.

2.4 GHz

Today, Public Safety operators, have access to channel assignments in the 2450-2484 MHz band on a shared basis with TV broadcasters. How well this arrangement works is completely dependent to the size of the city/county. In small or rural areas, with a small number of broadcasters, it works quite well. In larger cities, with multiple broadcasters, it doesn't work well at all. Public Safety customers have to share channels 8 and 9 with area and "itinerant" broadcast users who have both portable and fixed channel assignments.

In addition to sharing these channels with other licensed users, this band is also occupied by unlicensed services in the ISM (Industrial Scientific and Medical) band; 2400-2500 MHz. The most notable of these are Wi-Fi operators. These services are "low-power", and typically use omnidirectional antennas. Interference from these unlicensed users is therefore prevalent when the associated interfering transmitters are close to the Public Safety user's receiver. Users with receive sites in rural areas, geographically removed from the Wi-Fi and other interfering signals, have a reasonable expectation of successful operation to the calculated system range. Users with receivers located in areas where the interfering signals are strong will experience drastically reduced system ranges.

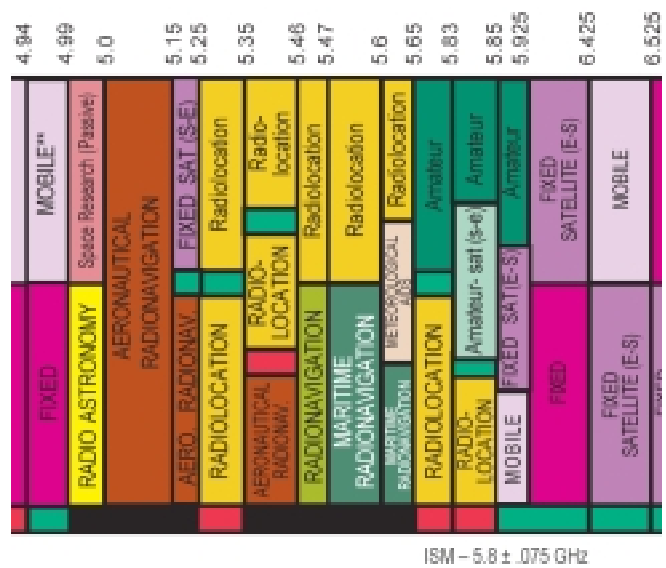

Figure 11

4.9 GHz

This is a fairly new band (at the time of this writing), and has very few operators using it. The good news is that the band is set-aside for Public Safety operators only. Therefore potential interference could come from other agencies within the community. Frequency plans are under development, and are likely to vary across the country. Some areas will use this band for video services, while others will use the band for wireless LAN/WAN services. How practical this band will be for video downlinks will be locally determined, and it's too early to fully define this practicality at this time.

In addition to this interference issue, it should be noted that a user must get both a license for use of the band, and a waiver to use the system in an airborne. The

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reason for the waiver is that this band is also used for radio astronomy, and detailed interference studies are requires insuring that the downlink does not interfere with this scientific use.

6.5 GHz

Public Safety operators, have access to channel assignments in the 6425-6525 MHz band on a shared basis with TV broadcasters, and LTTS (Local Television Transmission Service) operators. Its practicality from an "other licensed users" standpoint can be generally described, as is the 2.4 GHz band. In a large part of the country 6.5 GHz is underutilized. In other areas, like Los Angeles, there are man operators competing for the spectrum, and frequency coordination among the three communities authorized to use the band is required. This can be cumbersome.

Attractive things about this band are that terrestrial use is specified as mobile. There are no fixed point-to-point links in this band. It is shared with the field satellite uplink service and therefore has an ERP (Effective Radiated Power) restriction, however, interference between the two services has not been shown to be problematic.

Reducing Interference

Directional antennas can help reduce interference in two ways. They provide the receiver with a higher desired signal level, and by narrowing the beamwidth of the antenna, less undesired signals are presented to the receiver.

Essentially all receive systems available today are frequency agile, and the antennas are designed to cover an entire band, or bands. This allows tuning to different frequencies within the band, but also means that no protection is provided to the receiver from adjacent channels. Receivers are designed to deal with this environment, but in some cases, channel filters may be necessary to further reduce the level of incoming adjacent channels. This is most prevalent at strategic receive sites where multiple entities have receive systems installed.

When it comes to Wi-Fi and other co-channel interference, there's not much that can be done. Directional antennas may help somewhat. But extra filtering can do little, since the interference is inside the boundaries of the desired channel as well as adjacent to it.

Rough Numbers

The following table is intended for rough, first-pass, budgetary pricing only. The prices given are only intended as a comparative tool to help illustrate the rough costs of the various subsystems discussed. The prices given are for the equipment only. Installation is not included, as those prices vary widely according to site conditions. The equipment for the highest-priced frequency band is quoted.

System Description	ROM Equip. Cost
Digital Video Transmitter System with AES encryption, non-deployable omni antenna, and TX remoter control head	$36,000
Digital Video Transmitter System with AES encryption, high-gain auto-tracking antenna system and system controller.	$70,000
Tactical Digital Receive System (hand-held with built-in monitor) with transit case, battery pack, short-range (omni) antenna, medium-range antenna and tripod	$43,000
Tactical Digital Receive System (command-van, rack mounted uses external monitor) with omni antenna (short range only)	$14,500
Tactical Digital Receive System (command-van, rack mounted uses external monitor) with omni antenna and switchable sector antenna (medium range)	$32,000
Strategic Digital Receive System (rack mounted radio and local controller, uses external monitor) with automatically tracking high-gain antenna system, and remote control system. (long range)	$65,000

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Conclusions

Whether you're in the early phases of planning a video downlink, or getting ready to write your specification, it's important to plan for your current, and potential future missions. You may spend a few extra dollars in the beginning that will save you in the long run. Make sure you don't get locked into a system that won't provide the range you may need for future plans.

Do the research necessary on frequency band selection. No manufacturer or salesman can honestly make a blanket statement on a preferred frequency across the United States. The best band for your area of responsibility will vary according to local band usage.