BMS Primer on Microwave Downlinks for Public Safety & Law Enforcement

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TABLE OF CONTENTS

I. Introduction

Broadcast Microwave Services, Inc. (BMS) has taken the lead in developing an extensive digital product line for the mobile encoding and microwave transmission of video and audio. BMS also provides the system integration services necessary to deliver a complete microwave video solution to public safety & law enforcement agencies.

Versatility and quality are the hallmarks of BMS system solutions. Our products have been networked into comprehensive government surveillance systems that span large geographical areas on land and sea. BMS has designed a product line especially suited to the unique and vital needs of public safety and law enforcement agencies at the local, regional, and national levels. Examples include video capture and transmission from helicopters, emergency ground vehicles, and even from portable equipment in the backpacks of individual officers and rescue workers. The real-time information captured and distributed by BMS systems can make a lifesaving difference in medical emergencies, natural disasters, crime prevention, and multiple other law enforcement scenarios.

The purpose of this document is to provide an overview and benefits of the BMS microwave video downlink solutions that are tailored for public safety and law enforcement.

II. What is a Microwave Video Downlink?

Microwave Downlinks send video and data from an aircraft to a receiver on the ground. The video can be taken from any composite video source. Daytime, infrared (IR), and intensified cameras are just a few examples of video sources. Common digital video formats are also supported. The data is sent simultaneously down one of two available audio subcarriers at a rate up to 9600 baud over an RS232 link.

Video downlink as seen on the ground

III. Benefits of a Microwave Video Downlink

Microwave Downlinks have very different benefits for those in the air than for those on the ground. Because the downlink originates in the aircraft and is received on the ground, it is important to note the benefits for those on both sides of the link.

Benefits to the Aircrew

Assuming that the mission of the aircrew is to be an aerial observation platform, their job is to report what they see from the air to those on the ground. The benefit to the Aircrew is that there is no better way to describe what they see than to show it with live video. Microwave downlinks are the tool that sends what they see to the ground, live as it happens.

The old cliché of "A picture is worth a thousand words" really applies to this application. Video is a universal language that is understood by all. There is no misinterpretation; what you see is what is happening. Eliminating the need for analysis and interpretation from the cockpit also reduces the workload and stress of the air crew.

The aerial perspective is a valuable resource to the people on the ground that need to analyze and react to the events as they are happening. With the video downlink the air crew can communicate efficiently to a wide range of observers on the ground. The air crew's audio description of the scene is accompanied by live video to accurately describe a house fire to a firefighter, an incident scene to a swat commander, a high pursuit car chase with cross street call outs to a scene commander, or the location of a lost person to a search and rescue team.

Benefits to Ground Personnel

The benefits of live video to the ground personnel are even more obvious. "Seeing is believing." Microwave downlinks provide ground personnel with the best possible description of what is seen by airborne units, with no loss of information due to delays or interpretive descriptions. Gaining the aerial advantage is why the aircraft is in the air, and there is no better way of describing what is seen from the air than to SHOW it to the people on the ground.

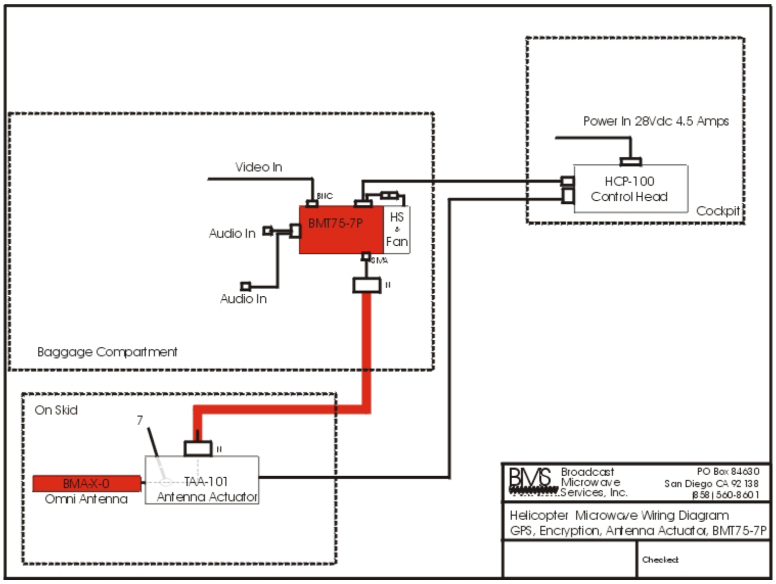
IV. Understanding the Types of Downlink Systems

It has often been stated that no two microwave systems are alike. However, all systems start with the same basic components: transmitters, receivers, and antennas.

Transmit Systems

The basic transmission system for all microwave downlinks includes a Transmitter, RF Cable and an Antenna. The simplest system utilizes an Omni directional antenna that does not require steering. The following block diagram shows the minimal required equipment in red.

Although this basic set of equipment will provide a simple and low cost downlink system, it is rarely the most practical type of system for airborne use. For Omni Directional Downlink systems BMS recommends adding a control panel so the crew can select frequencies and turn the unit on and off remotely. (See white items in the wiring diagram)

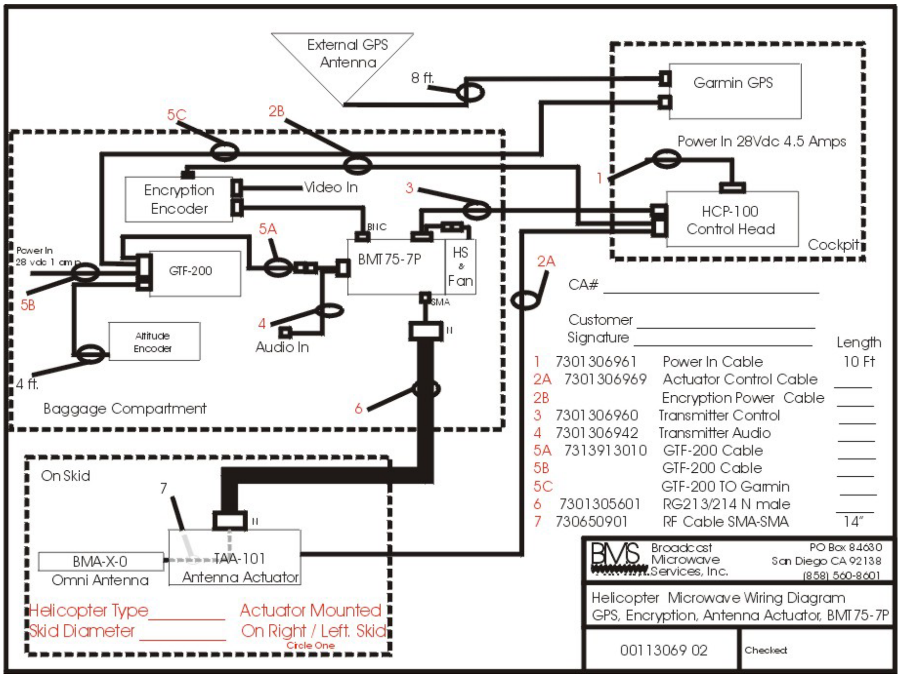


As an option to increase performance of the downlink, it is recommended that the skid mounted TAA-101 omni actuator be included to deploy the antenna below the skid while the aircraft is in flight. This skid mounted actuator places the antenna well below the lowest point of the aircraft, below the camera ball, Night Sun, and away from any equipment that could obstruct the line of sight or create significant multipath signals. Although the TAA-101 actuator is not a required system component, it vastly improves the performance and utility of the microwave system and allows the pilot to fly the aircraft with greater bank angles before any shadowing of the antenna occurs.


TAA-101 Omni Actuator System

Omni directional transmit systems have other benefits. Because the omni directional antenna broadcasts the signal in 360 degrees, it does not require pointing, and you can have an infinite number of receive sites simultaneously receiving the transmitted video and data. This means that you can have hand held receivers at the scene, suitcase receivers at the incident, a GTA24 tracking receiver at the mobile command vehicle, and a Silhouette tracking receiver site at headquarters. All sites can see the same live airborne video simultaneously.

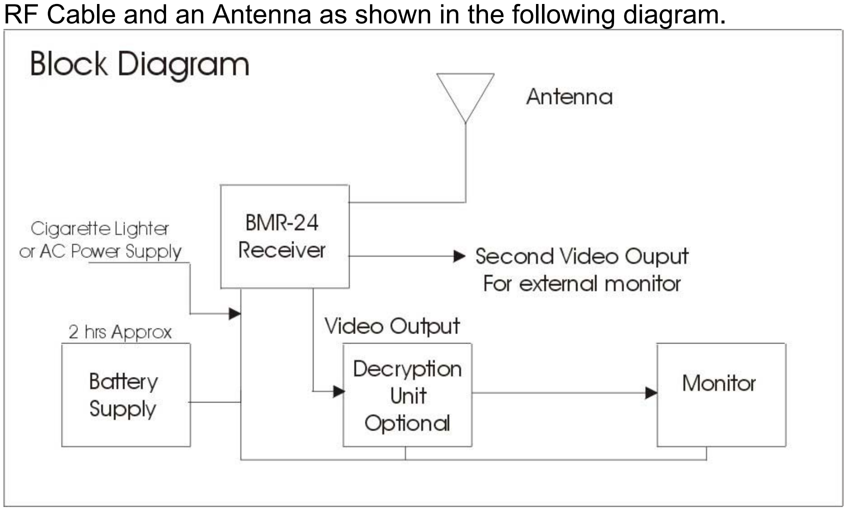
Omni directional transmit systems in the aircraft can transmit to both short and medium range receive sites. For longer ranges the simple omni antenna must be replaced with a high gain directional antenna. The GCA-4 high gain antenna is recommended for this purpose. This high gain antenna has a narrow beam width, much like a flashlight, and focuses the beam with greater power in only one direction. The antenna must be pointed at the receive site and it can not transmit to more than one receive site at a time.



The GCA-4 antenna system uses GPS to steer the antenna and point at the receive site. The operator needs only to input the coordinates of the receive site for the antenna to point. Significantly extended ranges are attainable by this system, but, as can be seen from the block diagram above, the system is more complex and expensive than an omni directional system.

Receive Systems

Like the Transmit system, the basic microwave downlink receive system includes a Receiver, RF Cable and an Antenna as shown in the following diagram.

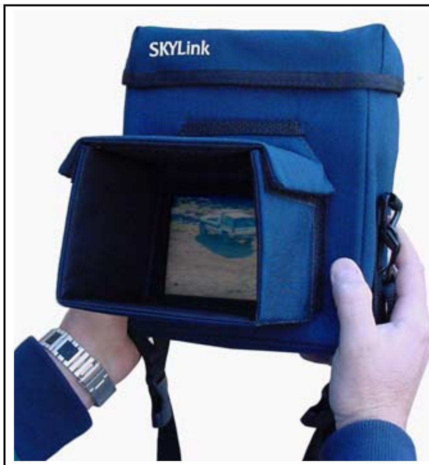


These systems can be enhanced by a variety of antennas, video viewing monitors, batteries, automatic GPS steering, and windows-based remote controls.

As with the transmitter systems, the choice of antennas determines the range of the downlink system. Antennas range from simple omni antennas that do not require pointing, to high gain antennas that have a narrow, flashlight-type beam width.

There are manually steered and GPS steered receivers. There are also receive systems that are more suitable in a mobile environment than those that maximize effectiveness on a fixed mountain top or building. For complete mobility and light weight, the SKYLink Hand Held Receivers or BMS Briefcase Receivers are self contained receive sites with batteries and a built-in monitor.

The SKYLink is a Hand Held receiver designed to be carried away from a car and into the field. SKYLink utilizes an Omni directional antenna which does not require pointing. Its range is limited to 3 miles at 6 GHz and 5 miles at 2.5 GHz. This unit is designed to *Grab and Go*.



SKYLink Hand Held

The BMS Briefcase Receiver is slightly larger and has options for a larger monitor. The larger battery pack also enables longer battery life. Other features include:

- A second video output port that can drive a large screen monitor in a mobile command vehicle
- The flexibility to easily swap out the omni antenna for a high gain manually pointed antenna for greater reception distances.

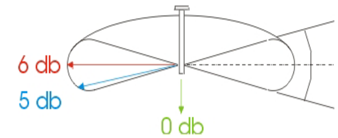
The GTA-24 GPS Tracking antenna is the perfect solution for Mobile Command Vehicles. This unit has both a high gain antenna for receiving a signal up to 20 miles away and an omni uplook antenna to receive signals from aircraft that is flying directly over head. The GTA-24 has its own GPS antenna and compass to identify its own location. Once it acquires the aircraft signal the GTA-24 automatically tracks the aircraft and chooses between the uplook and high gain antenna. The GTA-24 is small and light weight, enabling it to be easily transported and placed on a tripod for temporary receive sites in the field.

The Silhouette and Super Quad antenna systems have larger, higher gain antennas and are designed to receive from significantly longer ranges. These systems are installed at fixed sites with antenna pods that can be placed on mountain tops, tall buildings, or towers in order to increase the line of sight and range. Other features include user-friendly, Windows-based software controllers that can be connected via fiber optic or ordinary telephone links in order to remotely control the antenna pods from long distances.

Antenna Selection

The antenna can be the most important component of a microwave system. There are multiple antenna types available, each having a unique pattern and vastly different levels of performance. Therefore, proper selection of antennas is crucial to the quality and performance of a microwave system.

Antennas are measured by their gain and pattern. The gain is measured in decibels (dB) and should be thought of as an amplification of the signal. The antenna pattern determines the coverage direction and area of the antenna's coverage.



How to read an antenna Pattern:

Draw a line from the center point of the antenna pattern towards the receive site.

The length of the line where it intercepts the antenna pattern depicts the gain of the antenna.

At the horizon this antenna has 6 dB of gain.

At 10 degrees below the horizon it has 5 db of gain.

Directly below the antenna it has 0 db of gain

The two basic types of antennas are:

1. Omni directional.
   - Omni (Stick)
   - Patch
   - Discone
2. Directional (typically high gain antennas)
   - Yagi
   - Parabolic
   - Helical

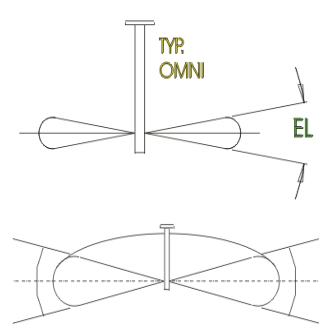
Omni Antennas

Omni directional antennas transmit or receive in a 360 degree pattern. Omni directional antennas are very popular because they do not require pointing, which also makes them the easiest to use.

There are three common types of omni directional antennas:

1. Dipole (stick) antenna
2. Patch antenna
3. Discone antenna

Although all three types of Omni antennas transmit or receive signals in a 360 degree pattern, the types of patterns themselves differ.



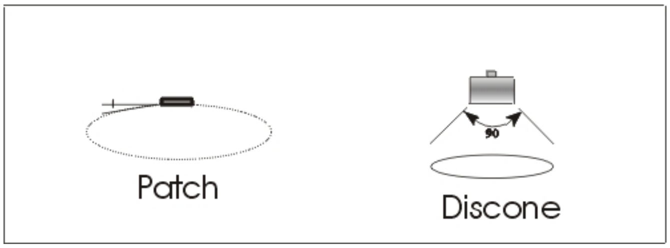
Omni Directional Antenna

The most common omni antenna, the dipole antenna, is often referred to simply as an Omni antenna. The dipole antenna is shaped like a stick or broom handle. Versions of dipole antennas appear on cellular phones, two-way radios, and car radio systems. The 360 degree pattern from an Omni antenna is shaped like a donut.

Dipole (stick antenna) with donut shaped pattern

Patch antennas are flat and can be rectangular or circular in shape. The patch antenna pattern is similar to a top hat or mushroom. The coverage of a patch antenna can reach the horizon, 180 degrees.

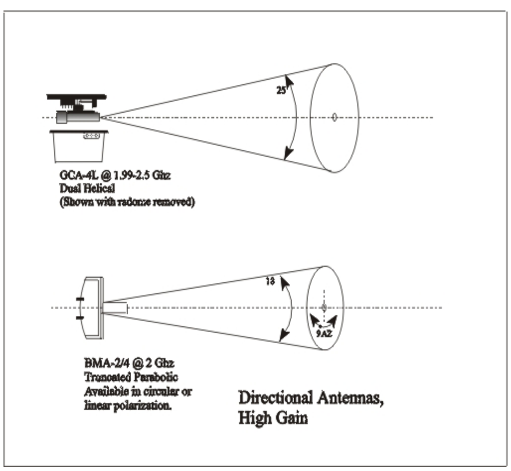
Discone antennas typically provide more gain than a patch or omni antenna, but do not reach all the way down to the horizon. Typical acceptance angles of discone antennas are in the 90 degree range.



Patch Antennas and Discone Antennas are omni antennas with a different pattern.

Directional (High Gain) Antennas

Typical high gain antennas include parabolic, horn, and yagis.



High Gain Directional antennas have a focused beam width and a conical coverage area. The higher the gain, the more focused the beam width becomes. Because of the conical antenna pattern, high gain antennas need to be pointed at the transmit or receive site. This is typically a simple issue until one or both of the sites are moving, as in the case of airborne microwave downlinks.

Pointing of high gain antennas can be done in several ways:

- manually (least expensive),
- Signal strength tracking or phase differential tracking
- GPS tracking.

Manual pointing requires someone to stand with the antenna and point it at the aircraft. One typically watches the signal strength meter on the receiver to peak the signal and keep the antenna pointed directly at the aircraft.

Phase differential tracking is an automatic tracking system. The downlink signal is picked up manually and then the tracking system electronically monitors the signal strength and points the receive antenna at the aircraft. This system works well until multipathing is present. Reflected signals can fool the tracking system and then disappear, leaving the antenna with no signal to track at all. When this happens the aircraft signal has to be manually re-acquired.

GPS tracking is the most popular and accurate way to point high gain antennas. GPS tracking uses the GPS coordinates of the transmit site (aircraft) and the receive site. Electronics then do the computations to point the antenna at the aircraft. The antenna is manually pointed at the aircraft, and once a signal is received the GPS coordinates of the aircraft are sent down the microwave link to the receive site. The GPS coordinates of the ground site are input at the time of installation for fixed sites and a dedicated GPS receiver is used for the mobile tracking antennas. Once the GPS coordinates are received from the aircraft the antenna's electronics take over and point the antenna. If the aircraft goes behind a building and the signal is temporarily lost, the antenna stops and waits for instructions.

GPS tracking antennas also have a search mode option that can be manually turned on to eliminate the need for manual pointing. Searching is an automatic way of acquiring the aircraft signal. A sector search looks in a 90 degree window for the aircraft; a continuous search rotates the antenna 360 degrees until the aircraft is located. Once the aircraft is located the antenna starts tracking automatically and continuously.

V. What Microwave Downlink System is best for you? Short, Medium, Long Range Systems

The following key questions must be answered in order to determine the type of BMS microwave system a customer needs:

Who on the ground needs to see the video?
Where on the ground are they located?

The table below summarizes typical responses to this question, the resulting distance requirements, and recommended BMS system solutions.

Note: All these systems use the same equipment in the aircraft. An aircraft equipped with an omni directional antenna can transmit to all the receive sites simultaneously.

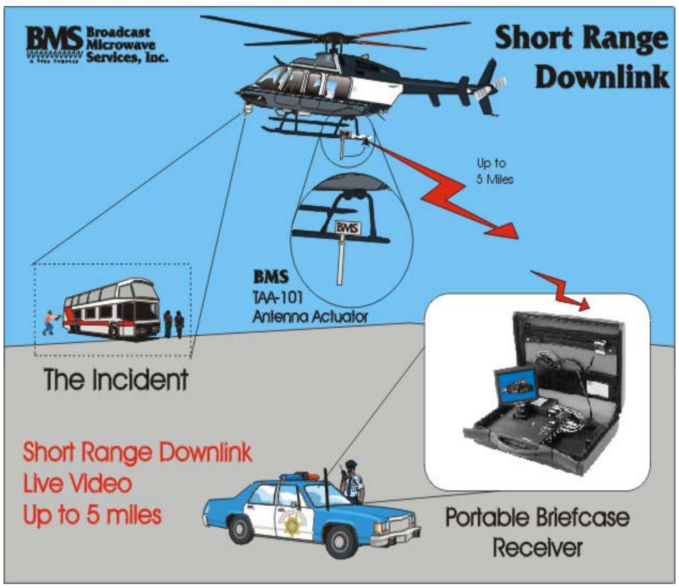
Location of Viewer on the Ground	Distance Requirements	BMS Solutions
A pedestrian on foot.	Short range	SKYLink system
In a car	Short range	Suitcase or mounted receiver
In a mobile command vehicle	Medium Range	GTA24 Mobile Tracking System
In a headquarters command center	Medium Range	Silhouette Tracking System

VI. Types of Microwave Downlink Systems

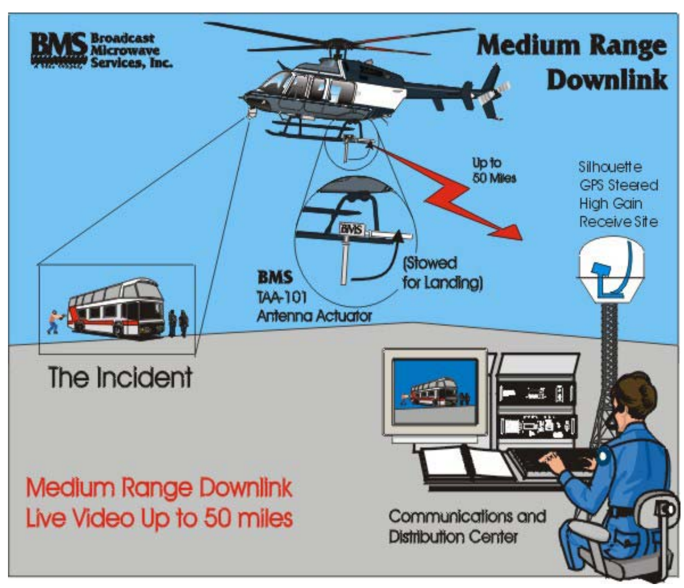
For the purpose of configuring microwave downlink systems, BMS groups the systems into three categories:

- Short Range   Omni Tx   Omni Rx
- Medium Range   Omni Tx   High Gain Rx
- Long Range   High Gain Tx   High Gain Rx

The antennas used on the transmit and receive sites are the primary factors that determine the range of each system. Maximum distances are based on the frequency, transmitter power, antenna gain, and losses from system cabling. Systems in the 2 GHz frequency range tend to perform better than systems in the 6 GHz range.

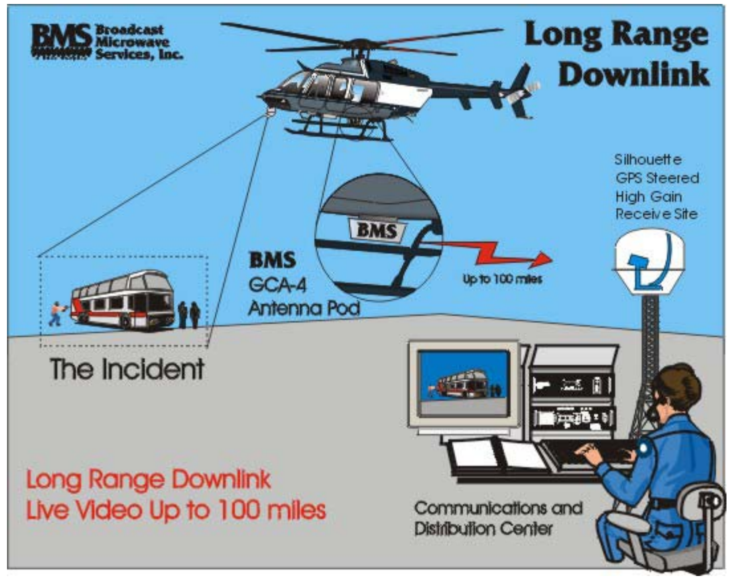


Transmit Antenna	Omni
Receive Antenna	Omni
Range	1 to 3 miles



Transmit Antenna	Omni
Receive Antenna	High gain
Range	Up to 50 miles

Transmit Antenna	High gain
Receive Antenna	High gain
Range	100+ miles

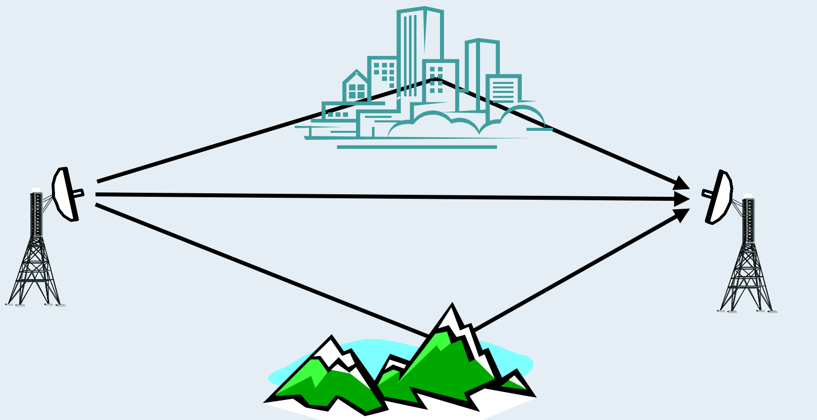


VII. Digital Microwave Technology

Analog Microwave systems require a direct line of sight. Having a direct line of sight increases the probability that the primary signal will be as strong as or even stronger than any secondary reflected signals. This is important because of the effects of Multipath propagation.

Multipath happens when the microwave signal is reflected off of buildings, water, or any surface, such that there are multiple signals entering the receive antenna. The analog receiver is "confused" by the additional signals, and the video output quality is poor. One can only hope the reflected signals have traveled much longer distances and have been attenuated to the extent that the receiver does not see them.

Digital microwave allows the receiver to process the signals in such a way that it is highly resistant to multipath. Consequently, digital microwave does not require line of sight transmission and signals appear to be received from around corners and through walls. BMS has selected Coded Orthogonal Frequency Division Multiplexing (COFDM) as the most effective digital modulation technology for its microwave products. COFDM involves modulating the data onto a large number of carriers and is well suited for advanced communications links that require resistance to multipath errors.



Because of obstacles and reflectors the transmitted signal arrives at the receiver from various directions over multiple paths. Multipath causes fluctuations in amplitude and phase as well as time delays in the received signals. COFDM digital can accommodate Non-line-of-sight transmission with high levels of multiplath propagation and still deliver a quality signal.

Some caution should be taken, however, when saying that digital microwave operates efficiently without line of sight. Digital Microwave provides exceptional pictures even with reflected non line of sight signals, but it does require a favorably reflected signal. This means that some signal has to be reflected to the receiver. In the case of going beyond the horizon, the reflected signal is sent into space. Mathematical models used to predict maximum distance are not reliable because it is impossible to predict the absorption properties of the reflectors and signal attenuation of walls that the path is going through.

Therefore, it is very important to conduct proper physical testing of the microwave environment to determine the degree to which a signal will penetrate walls or can be received around buildings. Every environment poses its own challenges and must be tested to determine how far a microwave signal can travel to get to the receive site.

VIII. Digital vs. Analog

Analog microwave systems have been in use for over 20 years. Analog microwave uses Frequency Modulation (FM)

Digital Microwave is a newer technology that is replacing analog microwave for many applications and for several reasons. BMS has selected Coded Orthogonal Frequency Division Multiplexing (COFDM) as the most effective digital modulation technology for its terrestrial microwave products.

Digital Microwave benefits:

- Requires 1/3 RF bandwidth of analog
- Resistant to multi-path
- Robust signal in non line-of-sight applications (even inside buildings)
- Digital signal processing adds all signals received to ensure accurate reception
- Error correction & encryption
- Useful for aircraft, vehicles or ships

- Existing antennas can be applied

Digital Microwave Disadvantages to consider:
- Can be costly when compared to analog
- Difficult to estimate coverage
- Increased power consumption
- Increased equipment size

Analog Benefits:
- In use for 20+ years
- Currently less expensive

Analog Disadvantages
- More RF bandwidth required for analog video
- Subject to multi-path, signal bouncing fades
- Lack of error correction
- Requires line-of-sight

IX. Frequency Allocation

In the United States frequencies are allocated for law enforcement and public safety agencies that obtain a license from the FCC. Similarly in other countries, the spectrum for law enforcement and public safety is commonly licensed by the national regulatory agencies. Therefore, it is necessary to review and understand the regulatory requirements for spectrum of each country in which a video microwave system is being considered. The following describes the allocation of frequencies for public safety and law enforcement in the United States.

2.4 - 2.5 GHz

In the US a license is required in the 2.4-2.5 GHz Band for the broadcast industry.

There are two channels at 2458.5 and 2475.5 MHz that have historically been used by Law Enforcement agencies in the past. These frequencies have now been set aside for Broadcast use as both fixed and mobile temporary ENG applications.

In the beginning, law enforcement agencies were allowed to obtain a license to use these channels by obtaining a waiver from the FCC for the intended use as surveillance links on the ground. These links were limited in power and as ground links they affected a relatively small area so that the broadcasters could work around the relatively small number of law enforcement links.

Soon law enforcement agencies began to receive waivers in order to place the microwave in aircraft. Once this occurred, the elevated transmit antennas began to interfere with broadcasters' applications. The Broadcasters protested and put an end to these waivers for law enforcement. A small number of agencies continue to operate under these waivers, but most are disallowed from using these two channels any longer.

The FCC has allowed the use of low power non-licensed radios in this band, but the proliferation of Wireless LANs and cordless phones in this band has made these frequencies impractical in large cities like Los Angeles and New York City. BMS does not recommend that law enforcement agencies use these bands any longer.

6.4 - 6.5 GHz

This is an Industrial common carrier band in the US that is available for multiple uses and is the band that most Law Enforcement agencies are now using for analog microwave downlinks. There are four channels that are 25 MHz apart.

4.94 - 4.99 GHz

Allocated for Law Enforcement and Public Safety ground applications (must apply for waivers for airborne applications).

The FCC has recently set aside the 4.94 to 4.99 GHz band exclusively for Law Enforcement and Public Safety use of digital radio ground technology. Because the wording in the docket applies only to ground digital radio applications, agencies must apply for waivers to use in airborne applications. Conditional waivers for airborne applications are being granted.

X. Conclusion

COFDM digital microwave provides clear advantages over alternative radio technologies in the delivery of video, audio, and data. These advantages are easily demonstrated over long distances and in unforgiving environments where significant multipath interference occurs.

The public safety and law enforcement scenarios shown in this document are only a sampling of the possible configurations of BMS video microwave downlink systems. Obvious advantages to these configurations are the mobility, flexibility and reliability that can be attained with the BMS digital microwave technology.

For over twenty years BMS has been in the business of developing high quality products for microwave applications. However, BMS is not just in the business of making microwave products; BMS is in the business of creating digital microwave solutions that are optimized to meet unique and vital requirements of public safety and law enforcement agencies.

To learn more about BMS solutions and experience in providing microwave video downlink systems to local, state, and national agencies, please inquire via email at sales@bms-inc.com or call 1-800-669-9667.