Microwave Downlinks
Constantly Evolving & Moving Forward

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“A picture is worth a thousand words” describes the true value of microwave downlinks. There is no better way to describe a scene to someone than to show him or her a live picture. Seeing is believing, and microwave downlinks build trust between the aircrew and ground personnel.

Much has changed in the last 10 years in the microwave downlink business. A decade ago, only a handful of airborne law enforcement agencies had microwave downlink systems. Broadcasters were quick to embrace the technology in their evening news in order to increase ratings, but law enforcement was slow to accept the technology. I believe this is partly because of a common misconception held by many pilots that the only thing that a microwave downlink could do was allow their boss to look over their shoulders. This misconception is far from true. In fact, microwave downlinks can be a benefit when used by a boss to monitor a pilot's actions.

Microwave downlinks simply transmit live video from an aircraft to people on the ground so the ground-based personnel can see what the aircrew sees.

Microwave downlinks are being used as a priceless marketing tool to promote air units by improving mutual aid between all first responders and air sections. If one of your missions is to be an aerial observation platform, then it is your job to observe and report what you see to those on the ground. There is no better way of doing this than to show them live video.

Video is a universal language. If you grew up in a SWAT environment, then describing a barricaded subject to a SWAT team on the ground will be no problem, but describing a fire to a battalion chief might be harder. Describing hurricane damage to an emergency management team may be impossible. Video transcends language and training barriers and promotes communications between agencies that don’t get to train enough together.

Microwave downlinks can make your aviation unit more valuable to more people. In these times when a “bean counter” might say, “Let’s get rid of the air unit; we can save a lot of money,” you want the SWAT commander to stand up and respond, “We can’t live without them!” You also want fire, emergency management and anyone else to whom you supply mutual aid to do the same.

Digital Revolution

Attitudes aren’t the only things that have changed when it comes to downlinks. The technology also has made quantum leaps in the last 10 years. Digital downlinks using coded orthogonal frequency division multiplexing (COFDM) were introduced in 2001. Prior to that, analog microwave downlinks used 20-year-old technology which had reached maturity. Analog (frequency modulation or FM) transmission worked but had many limitations. The two most important limitations were multipath and line-of-sight limitations.

Multipath is the phenomena that occurs when multiple reflected signals are received simultaneously at the receiver. In the analog world, these signals are added together, and Murphy’s Law says that more than 50 percent of the time the signals will be out of phase and destructive, rather than constructive. Multipath is the main reason that analog microwave downlinks are limited to line-of-sight applications. Line-of-sight means that the transmit antenna and receive antenna must have a clear path (line-of-sight) with no obstructions in order for the system to work.

Analog and digital microwave downlinks do not talk to each other. When an agency is considering its first purchase of a downlink system, it should purchase a digital one. The only time one should consider purchasing an analog system is when adding onto an existing analog system, or if you need to work with adjacent agencies that already have a significant amount of analog equipment. If the purchase is large enough, you should consider upgrading the entire region from analog to digital.

Digital microwave downlinks are far more robust than analog. They use forward error correction to eliminate the effects of multipath. The signal actually goes around corners and through walls, something that analog systems had a very hard time doing.

Before we go any further, I need to throw out this disclaimer: you still need a strong enough signal to get to your receiving antenna. The maximum distance will always be a line-of-sight transmission, and the signal will never go beyond the horizon because it is reflected into space. When the signal is bouncing off walls and going around corners, the mathematical equations used to calculate distance break down. Some materials (e.g. trees) attenuate the signal, some do not (buildings and walls). You get what you get when transmitting into buildings and non-line-of-sight situations; there are

no guarantees. Digital downlinks are the most robust available and have the best chance of getting a usable signal to the ground.

Gaining Diversity

The introduction of COFDM microwave was a quantum step up for the industry. A second step of equal size happened a couple of years ago. That was the introduction of diversity receivers.

Non-diversity or simple receivers have one antenna. Diversity receivers have two or more antennas (up to six). The signals from all the antennas are received and processed, resulting in a higher probability of at least one of the antennas receiving a good signal. A two-way diversity receiver will typically outperform its equivalent non-diversity receiver.

Diversity receivers use maximum ratio combining (MRC) to combine the signals from all the antennas. The easiest way to understand diversity reception is to think of it this way: each antenna pours its signal into a cup, and the video is drawn out of the bottom of the cup. All antenna inputs are used. This differs from older “voting” technologies that look at multiple antennas and choose the best signal from one antenna. MRC uses all the signals from all the antennas and does not throw away any of the antenna inputs.

The first auto-tracking systems used non-diversity receivers and required that the user be on the ground to acquire the aircraft before the auto-tracking antenna system could start auto-tracking. This was because these systems needed the GPS coordinates of the aircraft before they could calculate where to point the antenna, and the systems used the downlink to get the GPS coordinates from the aircraft to the tracking receive site.

Non-diversity systems had to be monitored by a trained operator. If the tracking system lost the aircraft signal because the aircraft went behind some type of obstruction like a building, the system would freeze and wait for input from either the operator or from the re-acquired signal from the aircraft.

One benefit of diversity reception is in diversity tracking receive sites. High gain directional antennas are arrayed in a circle. As an aircraft flies around the receive site, the diversity antennas automatically and seamlessly switch from antenna to antenna. These systems do not require operator intervention to acquire the aircraft. Auto-tracking is truly done automatically with no human intervention. Simply turn the system on and select the proper frequency.

With each generation of COFDM systems, there have been improvements in the weight, volume and power consumption of the aircraft systems.

The second generation transmit systems had two components: the transmitter and a amplifier. The components, with their shock mounting brackets, took up a total of 152 square inches of flat mounting surface. The third generation system has a combined transmitter and power amplifier and takes up 41 square inches of flat mounting surface. That is over a 300% decrease in mounting area. Power consumption was reduced from 262 watts to 170 watts. Weight losses were more modest but still came in at approximately one pound in weight savings.

Selecting a System

When considering the purchase of a microwave downlink system answer the following two questions. Who on the ground needs to see the video? Where are they located?

Your agency might have a different application, but here are four typical answers:

- On foot
- In a squad car
- In a mobile command post
- In a building

Each receive location requires a different receiver. When on foot, you want a small, light handheld receiver with omni-antennas that do not require pointing.

Some two-way diversity handheld receivers on the market weigh as little as three pounds. When an aircraft has a moving map system that can produce the center GPS coordinates of the direction in which a camera is pointing, the small handheld receivers can use the information to calculate the distance and bearing information to a target.

Here is one scenario where this feature may be used: late at night after a high-speed chase, the subject has abandoned his vehicle and fled into the woods. The aircraft has located the suspect in the woods with the FLIR camera. Officers on the ground, each equipped with a handheld receiver, are able to easily locate and surround the subject, and the receiver reports its distance and bearing angle to the subject. They can also see the downlinked video, which informs them of their position relative to the suspect and each other.

It is not hard to imagine that the suspect might draw a gun and point it into the darkness. Each officer will instantly see the gun and will be able to judge the danger they are in. Seeing the live video should also reduce the possibility of injury due to crossfire, as each team member can see each other and knows who and what is downrange.

The workload on the aircrew is reduced but their input is more valuable. Their main job now is to keep the subject in the center of the picture. The live video has reduced verbal instructions to a minimum.

When in a squad car, you may want a trunk-mounted diversity receiver (top center) with antennas mounted on the roof of the car. These systems can use the MDT’s video monitor or have separate monitor.

Briefcase receivers are a complete self-contained system like the handheld receivers but have bigger monitors so that more people can view the video. They are simply placed on the hood of the car with the antennas temporarily mounted to the roof.

Handheld receivers, trunk-mounted and briefcase receiver systems are designed to be at the scene within one to five miles of the aircraft.

Mobile command vehicles (top right) are much larger vehicles and quite often set up a safe distance from the scene. These systems typically have an air mast, which supports a diversity tracking antenna. Such systems can be 25 miles or more away from the scene.

The fourth and final receive scenario is on a building (top left, page 33). Buildings are at fixed locations and cannot move. They need a system that can track out as far as possible, which requires larger and heavier antenna systems. These systems are capable of receiving the aircraft out to 50 miles and more.

The Transmit Systems

There are two types of transmit systems for an aircraft. The major difference is in the antennas and the equipment that supports the antennas.

Omni-directional aircraft transmit systems use an omni-transmit antenna (top, page 30). Omni-directional antennas transmit the signal in 360 degrees and are the simpler, cheaper and lighter of the two systems. Because they transmit in 360 degrees, the antenna does not require pointing. The downside is that these systems will not go as far as the second type of system.

The second transmit system utilizes high-gain antennas, which focus the transmit energy. High-gain antennas need to be pointed at the receive site but offer a significant gain or stronger signal at the receive site when compared to an omni-directional system. These systems are typically mounted to the belly of the helicopter and are more complex than the omni antenna systems (top right, this page). They were designed for broadcasters whose mission is to get the video back to the studio.

High-gain systems can only point at one receive site at a time, and although many of the high-gain antenna pods have optional omni-directional downlook antennas for sending the signal directly under the aircraft, you still need to choose who gets the signal. Some systems split the power between the downlook and high-gain antennas. The result is less power to the high-gain antenna, which reduces its performance down to approximately what the omni-directional antenna systems do.

If your agency intends to downlink to any two of the above receive sites simultaneously, then the omni directional transmit system is the better choice. Omni transmit systems are cheaper, easier to use and far less complicated than high-gain systems.

Going Forward

Who knows exactly what is in the future, but one thing is for sure: HD cameras and HD downlinks will be there.

Downlinking the signal from an HD camera is rather difficult for current MPEG2 COFDM transmit systems. HD signals contain a huge amount of data as compared to a standard composite video signal. Downlinking large amounts of data forces less robust transmission schemes and less error correction to be used in the radio. When HD signals are being downlinked, the maximum path distance is reduced to approximately 1/7 the distance a similar system transmitting a standard definition signal. Because of this and the loss of robustness, most customers have chosen to downlink a standard definition signal.

Soon, HD downlinks will improve. New chip sets and H.264 video compression instead of MPEG2 will allow more robust transmission schemes and will regain most of the distance lost. These systems are due to come out in fourth quarter of 2009.

Remember that a picture is worth a thousand words, video is a universal language, and implementing a downlink system into your daily routine will make the air unit more valuable to those on the ground.