X-band for AISR

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Summary

U.S. government personnel were shown the performance of X-band for airborne intelligence, surveillance, and reconnaissance (AISR) applications. The demonstration proved that X-band can be used to provide a bandwidth efficient solution for transmitting ISR data at high data rates from an aircraft from a small (sub-meter) antenna. High data rates were achieved in a bandwidth efficient manner since spread spectrum techniques are not necessary for this type of application as they typically would using commercial Ku-band and Ka-band. In addition to these performance advantages, X-band frequencies occupy a part of the RF spectrum that is less susceptible to rain attenuation.

Demo Configuration

A demonstration of the value of X-band for AISR Beyond Line of Sight (BLOS) applications was witnessed at the Hagerstown Regional Airport in Hagerstown, MD. In this demo, a Dash 8 aircraft, provided by Leidos, with an X-band terminal was brought in for members of the government to inspect. This aircraft is equipped with a satellite terminal consisting of a Honeywell Wavestorm AS-X antenna, Newtec EL470 modem, and other ancillary equipment. The Wavestorm AS-X is a slotted array flat panel antenna with gains equivalent to a 0.4m parabolic antenna.

Details of the airplane's satellite terminal are available upon request. A 2.4m terminal located at the Mt. Jackson, VA Teleport acted as the hub terminal for this demonstration. The demo network is illustrated in Figure 1. Space segment for the demonstration was provided on the XTAR-LANT satellite located at 30°W longitude using the North American Spot Beam. Figures 2 and 3 provide footprints for this spot beam.

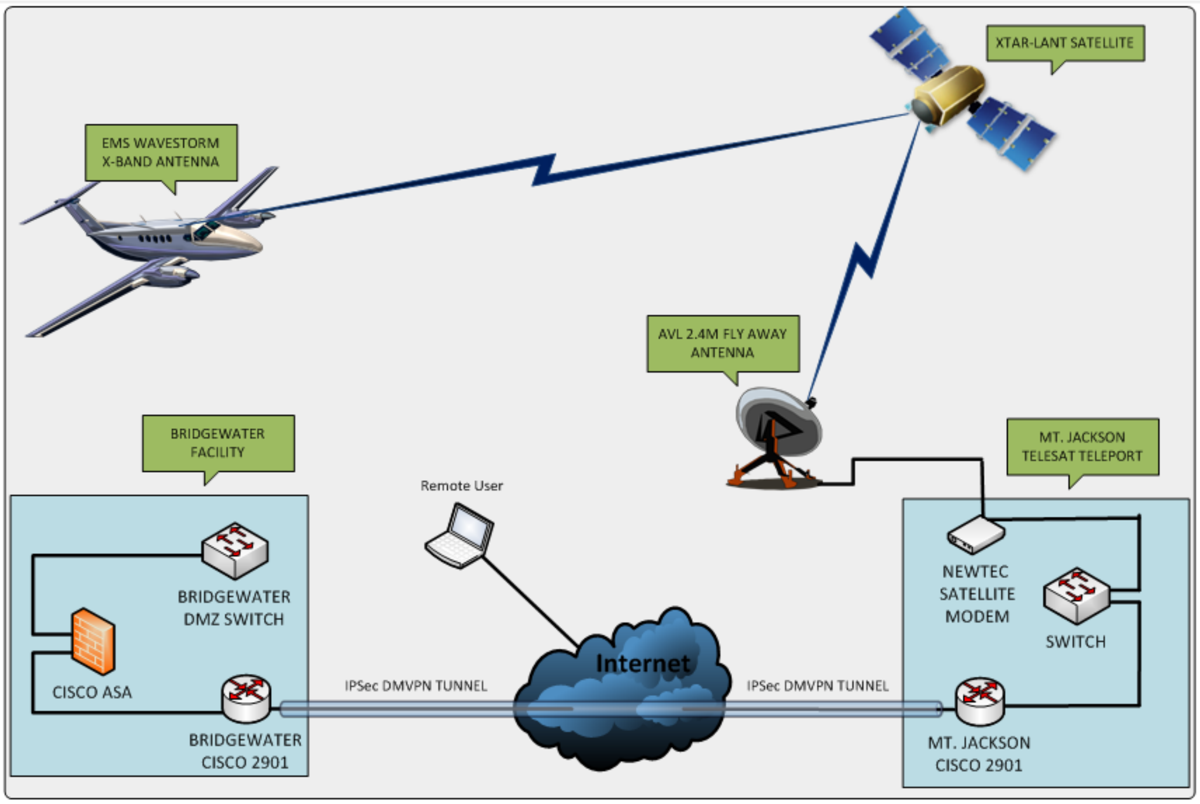

Figure 1. Demo Network Overview

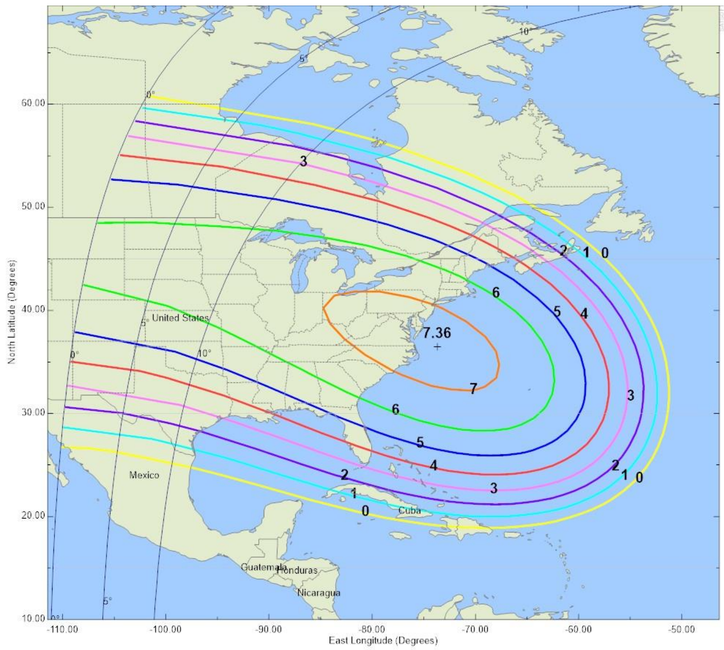

Figure 2. XTAR-LANT North American Spot Beam G/T (dB/K)

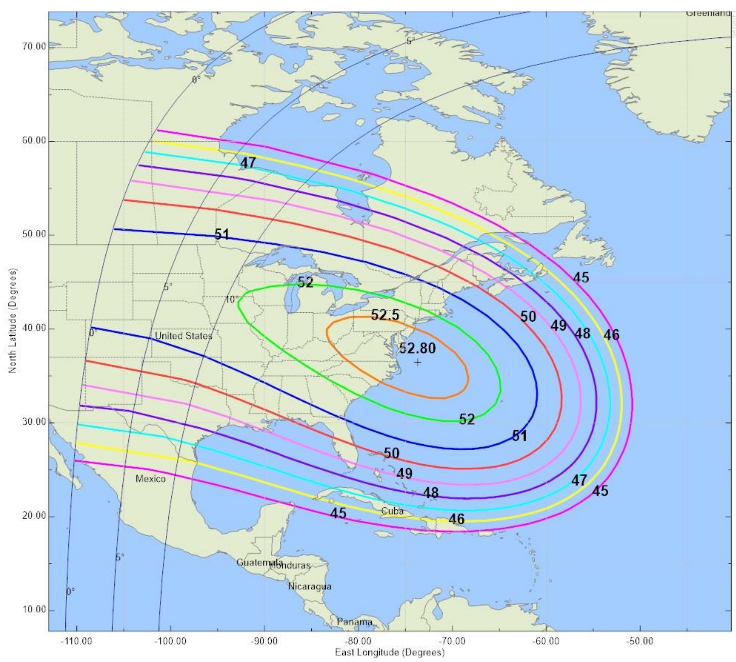

Figure 3. XTAR-LANT North America Spot Beam EIRP (dBW)

X-band was chosen as the frequency for this application for several reasons.

1. **High Data Rates**: X-band is capable of transmitting high data rates from small terminals. For this application (ISR), data rates of several Mbps are required to be transmitted off the airplane. Aircraft outfitted with the same equipment as the demo have successfully transmitted at data rates in excess of 10 Mbps in theater in an operational environment on XTAR's X-band satellites.

2. **Bandwidth Efficient**: X-band is bandwidth efficient. Not only are high data rates possible, but also high data rates can be achieved efficiently when compared to commercial Ku-band and Ka-band that have satellite spacing of 2° (sometimes less). This tight satellite spacing results in coordination agreements with neighboring satellites that limit the uplink power density that can be transmitted from the terminal and also limit the downlink power density of the satellite carrier being received by a terminal. When using a sub-meter antenna with a wide beamwidth, carriers are often required to use spread spectrum techniques to remain within the coordinated power density limits. In X-band, satellite spacing is 4° or greater. As a result, coordinated uplink and downlink power densities are much greater than can be achieved with Ku-band and commercial Ka-band. These greater uplink and downlink power density limits result in satellite links that generally do not require spread spectrum to remain within limits. For the demonstration, links of 10/2 Mbps were achieved with a total occupied bandwidth of 13.6 MHz (0.88 bps/Hz).

3. **High Link Availability**: X-band provides links with high availability. X-band satellites operate at frequencies below 10 GHz (7.25 to 7.75 GHz receive and 7.9 to 8.4 GHz transmit) and are therefore less susceptible to rain attenuation. This is important for manned ISR operations that operate below cloud cover. With this advantage, X-band links can operate at higher availabilities with a given link margin, or require less link margin to achieve a given link availability than Ku-band or Ka-band satellite links. In addition, techniques such as uplink power control, which require higher power terminals, or adaptive coding and modulation (ACM), which reduce data rates to maintain links in degraded weather conditions, are typically not required for X-band links.

4. **Low Probability of Interference**: X-band is less susceptible to satellite interference. As mentioned earlier the greater spacing between X-band satellites means less adjacent satellite interference. This is especially important when using sub-meter antennas as required for AISR. Cross-pol interference is typically less due to the use of circular polarization (no need for polarization alignment such as in Ku-band). In addition, since X-band is designated for government use, there is a smaller, well-defined user base and accidental interference from a rogue transmitter or a terminal transmitting on an incorrect frequency is less prevalent.

Demonstration

The link was designed for a nominal data rate of 10 Mbps air-to-ground and 2 Mbps ground-to-air. A link budget summary is available upon request. The links operate with adaptive modulation and coding (ACM) in both directions so the data rates vary with conditions (antenna blockage/movement, weather, etc). EL470 modem configurations settings for the test included;

1. Symbol rate of 8.892 Msps
2. ACM on and set for 1 dB minimum margin (minimum QPSK rate 1/2 and maximum 8PSK rate 9/10)
3. Layer 2 Ethernet Bridge between modems
4. XPE Encapsulation
5. CRCs enabled
6. 20% roll off factor
7. Normal FEC Frame Type
8. Pilots Insertion On

Applications demonstrated over the satellite link included;

1. HD video: UDP video stream with H.264 video coding
2. File transfer: FTP file transfer of files of 50 Mbyte, 100 Mbyte, 250 Mbyte, and 500 Mbyte
3. Ping: Constant pings during the flight
4. Chat: Bi-directional chat application between the air and ground.

Results

The demonstration was successful and showed that X-band is a viable choice for AISR applications. The airplane was flown for a period of approximately 45 minutes performing several maneuvers during that time. The satellite links remained up during the flight and passed data during the entire demonstration. Figure 4 shows the spectrum of the carriers during the test. The green line represents the maximum carrier levels and the red line shows the minimum carrier levels. The ground-to-air carrier is constant during the entire test, while the air-to-ground carrier varied approximately 2 dB due to the maneuvers performed by the airplane.

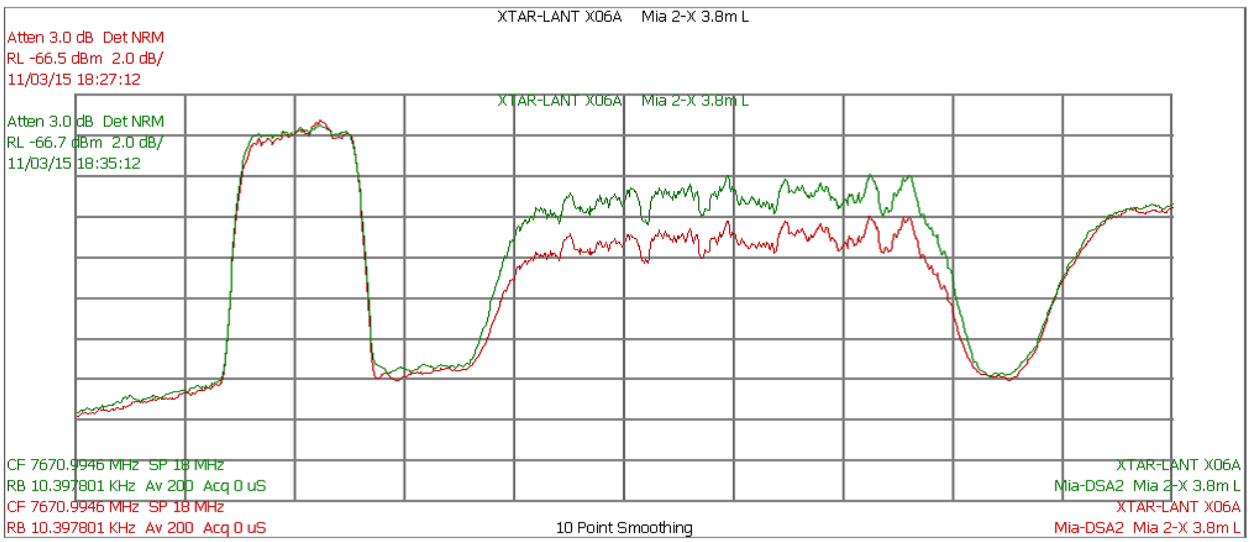

Figure 4.

Specific test results include:

1. Highest interface data rate transmitted air-to-ground was 12.6 Mbps with an average of 10 Mbps in less than 10.7 MHz of bandwidth.
2. Video was received air to ground with no significant outages throughout bank angles of 40 degrees and greater.
3. File transfer times (file transfer was simultaneous with video streaming and all other applications) were just under one minute for 50 Mbyte file, just under 2 minutes for 100 Mbyte file, just under 5 minutes for 250 Mbyte file, and just under 10 minutes for 500 Mbyte file.

4. Ping times were approximately 60 msec Hagerstown to Mt Jackson round trip and approximately 670 msec Hagerstown to Mt Jackson to aircraft round trip.

Conclusion

X-band appears to be a good choice for AISR and other applications requiring high data rate transmitted by small antennas. The demonstration showed that high data rates could be achieved through commercially available X-band space segment. The links were bandwidth efficient since spread spectrum techniques were not required. Applications, such as manned ISR missions, that require operation below cloud cover may benefit from the relative low immunity to rain attenuation when compared to Ku-Band and Ka-Band.

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