Antennas in Unattended Ground Sensor (UGS) Systems

Introduction

Intrusion detection and perimeter monitoring are key ingredients of network based defence. Detection and monitoring will revolve around finding new and innovative ways of using new and existing sensor technology.

Unattended Ground Sensors (UGS) have proven to be invaluable in various military missions. UGS systems make use of numerous low-power sensors to add to the capability of reconnaissance and surveillance. Sensor nodes may contain a combination of both passive and active sensor types, such as acoustic, magnetic, and seismic detection sensors, and potentially nuclear, biological and chemical (NBC) sensors. Each sensor also contains a low power transceiver to enable connections to Command and Control systems via Tactical Internet.

The networked communications requirements for UGS systems have spawned numerous developments in the area of low profile, low cost, yet high performance transceivers. A primary objective for these next-generation unattended devices is maximum mission life; hence the radios must employ low power circuit designs, and also power-efficient routing protocols and fast acquisition waveforms to support duty cycling.

The network architecture of the systems employing these transceivers is similarly optimized. Typically low power transceivers form a local network in which relatively closely spaced nodes, typically front line sensors, are interconnected.

As with any wireless connection, the antennas employed at the different communication nodes play an important part in securing the quality of the connection.

Antenna Considerations

UGS units are often located at or below ground level in an effort to reduce the visual signature. UGS system communication is thus affected by the physics of radio frequency (RF) propagation at low elevations. Depending on the carrier frequency of the signal and the terrain between the transmitting and the receiving end, the signal may take different modes of propagation like the direct wave, the ground wave or the scattered wave. In addition to the free space path loss which is always present there are also numerous other phenomena that may cause attenuation to the signal like reflections, scattering, diffraction and shading due to obstacles as well as attenuation due to vegetation, rain or any other lossy material located in the path of the signal. Further on, any objects (e.g. the earth ground) located in the near field of the transceiver antenna will inevitably shape the radiation pattern of the antenna.

Some generally desired requirements of UGS networks are the following:

- high data rate (over 1 Mbits/s)
- point-to-multipoint or mesh type networks
- high lifetime on battery use
- low visibility
- easy deployment in operational use
- usage in forest type terrain

These requirements have a direct impact on the specifications of the antennas to be used in UGS networks. The required high bit rates have the immediate consequence that in most practical cases relatively high carrier frequencies (at least hundreds of MHz, mostly GHz range) need to be used. There one should, however, keep in mind that with other parameters staying constant but only the frequency doubling, the free space path loss will halve the available connection distance.

In a mesh type network every node needs to be able to keep contact to several other nodes in different directions. This means that in most cases the antenna has to have an omni-directional radiation pattern. Also wide angle directional patterns may find use with nodes located at the edge of the network. The easy deployment requirement calls for a simple installation procedure where accurate alignment of the antennas should not be required. This further underlines the assumption that high gain directional antennas will not be too practical in these applications.

Battery based UGS nodes will not be able to use high transmission power, at least for long periods. Even though the communication waveforms will utilise all possible power saving aspects, high antenna efficiency will be very desirable.

Maybe the single most important property of the antenna affecting the quality of the connection of a node to its network, however, is the placement of the antenna and the resulting RF path. For a compact system which is easy to deploy and for reasons of low probability of detection (LPD) it would seem most convenient to place the antenna directly on the UGS node equipment which will be placed on the ground or even dug into the ground. For the RF connection, however, this location is everything else but optimal. At lower frequencies (below 500 MHz) the radiation towards low angles above ground is strongly affected by the cancelling effect of the ground reflection, whereas at higher frequencies the attenuation caused by vegetation becomes more and more important. Whatever the frequency, a low location of the antenna increases the probability of having important obstacles in the line of sight of the connection. So depending on the distance between the nodes, the available transmission power and receiver sensitivity, it may well be necessary to somehow place the antenna a bit higher above ground. Whatever the practical implementation, one needs to make sure that the achieved gain by doing so is not lost in cable losses and poor antenna efficiency.

Conclusion

UGS antenna solutions must be thought of carefully because of some very conflicting requirements. The most important decision to be made is the choice of the frequency to be used, as this will affect everything else. But regardless of the frequency, the antenna solution will most probably have to have high efficiency in converting RF power to radio waves, it will in most cases employ omni-directional antennas and it will have to have placement options to overcome the problems of difficult node locations.

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