Key Engineering Factors in Satellite Communications

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Satellite communications is an "...indispensible part of our daily world of communicating." [1]. This month, we offer a few notes reminding us of the special engineering issues that affect the design of systems and equipment for satellite communications. We'll take a brief look at geostationary, low earth orbit (LEO) and the Global Positioning System (GPS).

Geostationary systems

The advantage of geostationary systems is that earth station antennas can be fixed because the satellite appears stationary. Technical matters to be addressed include the following:

Antenna beamwidth and sidelobes — The geostationary distance is heavily populated. Often, satellites sharing the same spectrum are located just a few degrees apart as seen from earth. Earth station antennas must be able to discriminate one satellite's signal from another using a narrow beamwidth and alternate polarization. One reason for increased usage of higher microwave frequencies is that smaller antennas can achieve the required beamwidth.

Propagation effects — Significant propagation losses are encountered in the 22,300 mile one-way signal path. Low noise receiver performance and sufficient transmitter power are required to maintain reliable communications. As the frequency used increases, atmospheric losses due to rain, humidity also affect the system design.

Time delay — Signals traveling over the distance to and from the satellite experience about 1/3 second time delay. In real-time voice communications, this is simply a little confusing, but in two-way data communications, any data that requires handshaking or other response mechanism must deal with this delay.

All of these factors make geostationary systems unattractive for mobile satellite communications [2, 3]. These technical factors are all difficult to achieve in a mobile environment. Some systems may justify the cost and complexity (e.g. INMARSAT communications on commercial aircraft), but most mobile satellite applications are now being addressed with low or medium earth orbit (LEO and MEO) systems.

Low earth orbit systems

LEO systems may remove the problems of propagation losses and their resulting equipment requirements, but there are some additional issues, ones that led to early skepticism of LEO system viability, that require innovative technical solutions:

Motion through the sky — LEO satellites' motion produces a significant Doppler shift, rising and falling in frequency as they approach, then pass the point nearest the user. Tracking and compensation must be included in any LEO operating system. This motion also means changing angles for signal transmission and reception. Unlike geostationary systems, LEO systems must have antennas with very wide beamwidth, to provide coverage over much of the overhead sky. In addition, as the angle of incidence changes, the signal losses change according to distance and the amount of atmosphere that the signal must penetrate. This adds a certain dynamic range that must be accommodated in the system, unlike geostationary systems, where losses are relatively constant and fixed performance parameters are usually sufficient.

Multiple satellites in the system — Because LEO satellites are only visible to a user for a fraction of their orbit, a large number of them must be place in various orbits to provide worldwide coverage. Some of the issues with multiple stations are similar to cellular communications, where users are "handed off" to the next base station as they travel. However, terrestrial cellular base stations are directly interconnected by telephone lines or microwave links.

Satellite "cell sites" must be linked by additional radio channels that have the same technical challenges as the satellite-to-user links. This might be done with a series of ground stations, in sufficient number to "see" all of the orbiting satellites, or it might be accomplished with geostationary satellites that provide coverage of nearly 1/3 of the earth (and near-earth orbital space), like is done with the TDRSS system for Space Shuttle communications.. Finally, all coordinating stations must be linked together to complete the system.

In addition to satellite-to-base station linking is the possibility of direct satellite-to-satellite links. This technique can simplify the support infrastructure, but can also complicate the overall technical requirements, since such linking is much more complex in its architecture than other options.

Global Positioning System

Another major satellite system is GPS, a government-sponsored 24-satellite system for precise identification of the user's location. Engineering issues of greatest concern for GPS involve accuracy enhancement and integration of GPS into other systems.

The greatest technical challenge in GPS was to integrate the necessary processing — for the acquisition of signals from the satellites and derivation of position data from the time of arrival signal and the encoded data — into low cost, compact GPS products. Other issues of wider scope are:

Antenna performance, electrical and mechanical — GPS receivers are being included in many mobile systems, requiring installation in everything from railroad locomotives to backpacks. This wide variety creates mechanical challenges, such as exposure to the weather, incorporation into existing vehicle construction, and aesthetic factors to minimize antenna visibility.

Electrical performance issues fall in two areas. The first is maintaining the appropriate response pattern, so that the GPS satellites can be reliably received. A nearly hemispherical pattern is required.

The second issue is obtaining the desired performance within the mechanical limitations of portable receivers, antennas that must conform an automobile body, or other installation requirements. Antenna engineers must come up with some very creative designs.

Accuracy enhancement — For the next few years, GPS will remain intentionally "dithered" for commercial users, resulting in reduced precision. Techniques to work around this limitation include differential GPS, where indicated position is compared to a nearby known fixed position. This technique is used in surveying and in new aircraft landing systems. Integration techniques over time are also applied to the matter of GPS accuracy.

Summary

Hopefully, this short review of the technical issues in satellite system engineering adds a little more information to your knowledge of various types of wireless communications. ■

References

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