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LEO systems present new problems for RF engineers

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Measuring QPSK modulation in personal/mobile satellite communication systems

Big LEO systems are the future for mobile and data communications. However, measuring the QPSK-modulated signals can be a challenge.

By Steve Reyes

A number of emerging personal mobile satellite communications systems are positioned to turn on in the near future. Market drivers for these systems include global mobile telecom users, high-speed data needs (Fax, Internet) and remote stationary locations (rural areas and global small villages). An additional anticipated market is providing global paging services combined with the mobile phone.

One of the satellite options is the Low Earth Orbit (LEO) system that operates in the newly licensed Ka and C bands where wide-data bandwidth are readily available. A major concern of the LEO system engineer is the accurate monitoring of power during operation. Recent advances in power meter design have introduced new measurement techniques that give satellite system operators the ability to monitor the short- and long-term power status under operating conditions.

Two of the new systems, Globalstar and Iridium, are known as Big LEOs. Big LEO systems are satellite systems that provide voice and data communication. Little LEO systems are systems that do not provide voice connections. These systems provide packet data links, or "store and forward" services, for data such as electronic mail, paging, digital messages and other commercial services.

A primary characteristic of the LEO system compared to the traditional geostationary (GEO) system is the low altitude. Low altitude results in the satellites not having a stationary position on the horizon. So, a larger number of satellites are required in multiple planes to maintain connections. Other differences between LEO systems and GEO systems are found in the time delay and the power requirements of the personal mobile phone.

GEO satellites have a typical orbit of more than 35,000 km compared to a typical LEO orbit of 700–1,400 km. Advances in GEO satellite technology have recently reduced the size requirements of the end user terminal and can now be handled by very small aperture terminals (VSATs). A drawback of VSATs in telecommunications is the two-way time delay caused by the altitude of the orbit. The typical voice interaction delay for GEO systems is from 600–1,400 msec, although LEO systems have a typical delay in the 300–500 msec range for local connections and 900 milliseconds for intercontinental connections. Also, the VSATs still are not truly portable and are not considered a personal mobile communication device.

The fixed orbit of a GEO satellite allows a wide-distribution footprint for maximum coverage per satellite. A GEO system requires only three to four satellites for global coverage while the LEO systems need 12–66 satellites for complete coverage. The number varies depending on the altitude of the satellites, the planned capacity of the system and other market objectives. As the number of satellites increase, there is more opportunity to cover a larger area of the globe and to provide a higher average elevation angle. A high-elevation angle reduces the effects of shadowing (blockages of the signal caused by buildings, trees) and results in less likelihood of a dropped call.

Table 1 provides a summary of the big LEO systems with comparison to

	GEO	Globalstar	IRIDIUM
# Satellites	4–6	48	66
# Planes	1	8	6
Altitude (km)	36,000	1,401	785
Modulation	QAM	QPSK	QPSK
Mobile User Uplink (GHz) Downlink (GHz)		1.610–1.6265 2.4835–2.500	1.616–1.6265 1.616–1.6265
Gateway Terminal	C/S Band K band (VSATs)	C Band Uplink / Downlink	Uplink 27.5–30.0 GHz Downlink 18.8–20.2 GHz
Avg. Satellite Connection Time		10–12 min	9 min
Transponder		Bent Pipe	Processing
Two Way Time Delay (millisec.)	600–1,400	300 local 900 intercontinental	300 local 900 intercontinental
Sat Mission Life (yrs)	10–15	7.5	5
Crosslinks	No	No	Yes; 4 crosslinks at 25 Mbps; 22.55–23.55 GHz
Data Rate (kb/s)	2.4 to 1.5 Mb/s	1.2–9.6 (Voice & Data)	4.8 (Voice) 2.4 (Data)
Battery Life		24 hrs standby, 8 hrs @ 5% duty cycle	24 hrs: 1 hr talk, 23 hrs standby

Table 1. Satellite communication systems.

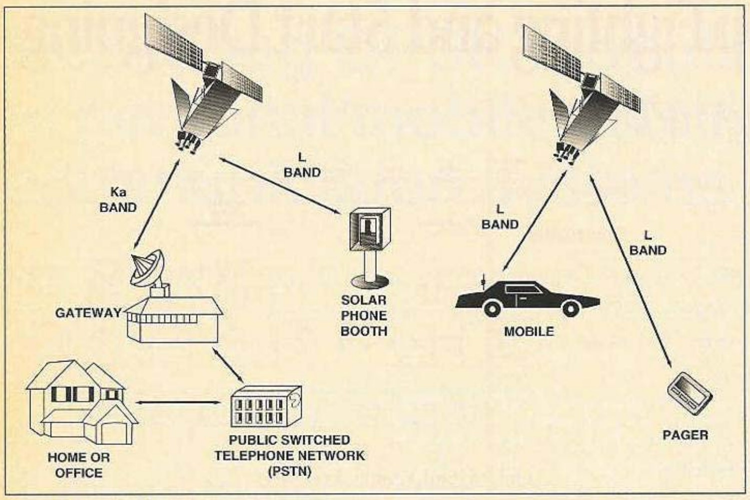

Figure 1. A typical big LEO system.

the traditional GEO systems. The big LEOs establish connections between the earth stations and the satellites in the C and Ka bands, while mobile connections are made via the handsets in the L and S bands. The earth stations may also double as gateways that provide connection to the local public switched telephone network (PSTN). Connections between earth stations are provided either through crosslinks between satellites, as in the IRIDIUM system, or through leased lines in other systems. Figure 1 provides an overview of a big LEO system.

Satellite modulation techniques

LEO systems use quadrature phase-shift keying (QPSK) modulation for maximum channel efficiency. Although there are different variations of QPSK modulation, the basic structure is the use of all four quadrants of the constellation. Figure 2 provides an example of a QPSK modulated signal used in a typical communication system. The four clusters represent the points of data available when using this technique. The tighter the clusters, the lower the bit error rate (BER). As the phase of the carrier signal shifts from one quadrant to another, the

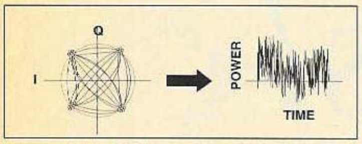

Figure 2. The QPSK-modulated signal experiences random power level fluctuations during the modulation process. The power amplitude chart gives an indication of the wide range of amplitude variations the carrier signal will track under a real-world condition.

signal vector often passes near or through the zero crossing. Because the distance from the zero crossing represents amplitude, Figure 2 indicates that the QPSK modulated signal experiences random power level fluctuations during the modulation process. The power amplitude chart in Figure 2 gives an indication of the wide range of amplitude variations the carrier signal will track under a real-world condition.

In satellite systems, there is a need to constantly monitor the power output of the satellite and ground stations. In low-power portable systems, issues such as building penetration, rain and tree attenuation, and horizon tracking result in the need to establish link budgets at the mobile phone, the satellite and ground station with margins as high as 20 dB or more. Consequently, accurate power measurements are critical to the success of the satellite system.

Power meter measurements

Power meters are ideal for monitoring the power transmission of satellite systems because of their accuracy, stability, and when available, user features. Diode sensors provide the best method for characterizing a complex modulated signal because of their ability of tracking the power envelope.

A diode sensor provides a voltage output proportional to power input within the square-law region of the diode, –70 to –20 dBm. This is often referred to as the linear region of the power sensor. Because diode sensors have a wide RF bandwidth, frequency modulated (FM) or phase modulated (PM) signals can be easily measured by diode sensors either inside the square law region or outside the square law region when non-linear correction factors are applied. However, if the signal is amplitude-modulated (AM), such as in the case of a QPSK modulated signal, then additional factors must be considered. If the power level of the modulated signal is within the square law region, then average power measurements are available when the meter is designed to properly take into account power variations. A properly designed power meter can accumulate multiple power readings of the modulated signal and average the data as long as the power level is within the square law region of the diode.

An additional challenge is encountered when the power level rises above –20 dBm and the diode is no longer in the square law region. In this case, the video bandwidth of the sensor, as well as the analog bandwidth of the meter front-end, must be wide enough to track the amplitude variations. If it is

provides a method of measuring a modulated signal outside the square law region and thereby providing the maximum dynamic range available for the measurement system.

A consequence of wider bandwidths in the measurement system is a reduction of dynamic range. To optimize measurement accuracy, power sensors with different bandwidths provide the opportunity to match the power sensor to the application while maintaining maximum dynamic range. A wide dynamic range offers the systems engineer the ability to accurately monitor the output of the system over the wide-link budgets typically found in satellite systems.

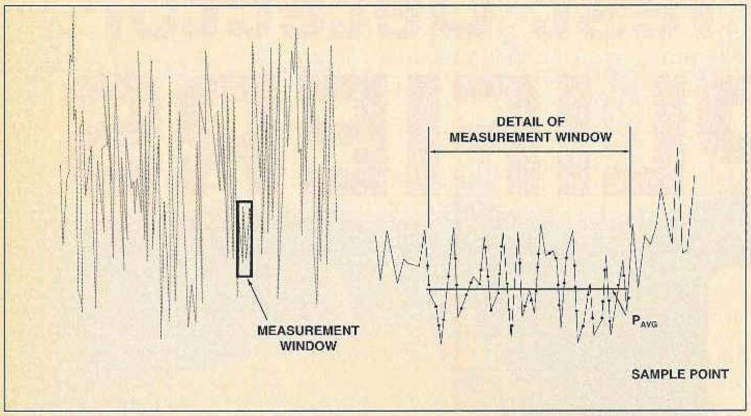

Figure 3. An example of an evenly distributed, random amplitude signal such as that found in a QPSK-modulated signal.

not, then a measurement offset will result. Diode sensors designed with the proper video bandwidth will track the power envelope and provide the power meter with sampled measurements ready for averaging. The bandwidth of the sensor must therefore be high enough to track the highest modulation rate of the communication system being measured. Using this approach

Measuring QPSK modulated signals

Figure 3 provides an example of an evenly distributed, random amplitude signal such as that found in a QPSK-modulated signal. Because the broad definition of power is the amount of energy per unit of time, the average power of a randomly modulated signal is the average power over the time pe-

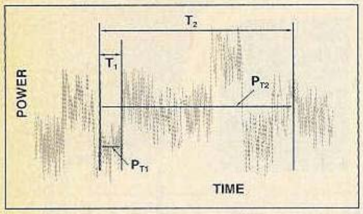

Figure 4. An example of the different levels of transmission that might exist in a communication channel.

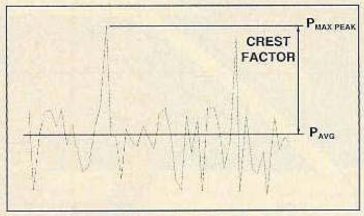

Figure 5. Crest factor is the ratio of the largest peak power encountered to the average power within the same measurement period.

riod of interest.

A diode-based power meter provides power measurements of an AM signal by accumulating sampled measurements over a period of time and providing an average. With random distribution of power, the power meter will arrive at the proper level when enough samples are accumulated. This time period can be indirectly controlled by the "Average N" number used.

Now consider a situation where the average power of the modulated signal varies with time caused by real-world conditions. For example, in a satellite communications system, the average transmitted power will vary with environmental conditions such as cloud cover, rain and changes in temperature. Also, changes in traffic occupancy cause variances in power output. Figure 4 provides an example of the different levels of transmission that might exist in a communication channel. A power measurement over time T1 will be different than a measurement over time T2 because of the difference in the times of the measurement window.

If the objective is to determine the power output of the transmitter at a specific point in time, then the power measurement window will have a relatively short duration. However, the systems operator often needs to analyze both the long-term uninterrupted power as well as the short-term power. In this case, a different method of data accumulation is needed. The difficulty with performing long-term power measurements under remote control is that the power meter often requires housekeeping chores, such as temperature compensation and display updates, that result in measurement gaps between readings. A power meter that takes into account this specific concern can provide an internal measurement mode that will eliminate meaurement gaps in the data.

Another important measurement of QPSK-modulated signals is crest factor. Crest factor is the ratio of the largest peak power encountered to the average power within the same measurement period (Figure 5). The systems engineer uses crest factor to track the largest peak power encountered during transmission. Limiting the peak power requirements to levels within the design parameters of the transmitter minimizes clipping or compression of the carrier and thereby minimizes BER during transmission.

Conclusion

The evolution of mobile communication systems has led to the development of personal communication satellite systems for global coverage. The big LEO systems will provide global personal services for voice and data for mobile as well as fixed remote-site access. These systems use QPSK modulation techniques for optimum performance of channel occupancy and data throughput. Accurate power measurements of QPSK-modulated signals can be challenging because of the constantly changing nature of the signal. Techniques have been developed that provide the capabilities necessary for a diode-based power meter to perform these measurements quickly and accurately. **RF**

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About the author

Steve Reyes is the marketing manager of the Instruments Division at Giga-tronics. He has been with Giga-tronics for four years. Steve has held various design development, sales and marketing positions in the microwave test and measurement industry for the last 19 years. He is a graduate of the University of California, Davis. He can be reached at 4650 Norris Canyon Rd., San Ramon CA 94583; Phone 800-726-4442. The 8540C Universal Power Meter from Giga-tronics provides all the capabilities discussed in this article. For more information, visit their Web site **www.gigatronics.com.**