GOOD TIMING

Fighting GPS Interference on the London Skyline

> "The **QUALITY OF TIMING AND SYNC** that goes into a telecom network in turn has real consequences for the **QUALITY OF DELIVERED VOICE, VIDEO AND DATA** services."

"OUR MAIN BUSINESS IS SYNCHRONIZING AND TIMING," says Chronos founder and Managing Director Prof. Charles Curry. "Our clients include Vodafone, Telefónica O2, Three UK and EE, the 'big ones' in British telecom, as well as a number of other UK and non-UK wireless and wire line carriers. With this group, we can speak from a well-informed position in the telecom synchronizing and timing business, at least in Britain."

Network synchronization, or "sync", is essential to all modern telecom networks. Sync ensures that telecom services are continuously available and reliable. And the quality of timing and sync that goes into a telecom network, in turn, has real consequences for the quality of delivered voice, video, and data services. In fact, timing and sync quality have become a key differentiator in the highly competitive telecom carrier market.

"Timing today does use GPS at core locations, with some backup technologies," Curry says, appending a caveat. "But GPS is vulnerable, and thus timing and sync are also vulnerable, especially to GPS jamming and other interference."

In a recent report on GNSS vulnerabilities, Chronos says that while today's Frequency Division Duplex (FDD) wireless telecom networks must meet a standard based on fractional frequency error—one part per billion—the incoming generation of 4G networks will use Time Division Duplex (TDD) techniques and a new performance metric, phase error, which requires sub-microsecond time accuracy.

New services and capabilities carried over these 4G networks, such as Coordinated Multipoint (CoMP) in which a handset communicates with a macro site and a small cell site simultaneously, will need a timing source with an accuracy of 500 nanoseconds, and this is at the edge of the network.

Some organizations are already providing this by using GPS alone, as is the case with Code Division Multiple Access (CDMA) networks. However, recent jamming attacks on South Korea by North Korea have demonstrated very clearly what can happen when GPS is compromised under this approach: numerous CDMA mobile phone sites lost their timing and failed.

A similar loss of cells was seen in the United States as far back as 2007 when a warship in San Diego harbor accidentally jammed GPS signals in the city, causing parts of the city's cellular networks to shut down for up to three hours.

SENTINEL

"As so much of our business depends on GPS, we wanted to know more about jamming, and we managed to find a generous source of funding in the form of the Innovate UK research program," says Curry. "We called our project 'SENTINEL.'"

The SENTINEL Project, which ran from 2011 to 2014, investigated a number of interconnected activities involving mission-critical or safety-critical services that need to be able to "trust" the accuracy and availability of GNSS signals at the point of use.

One simple but very important conclusion highlighted in the final project report was that the GPS jamming threat is getting worse.

"Under SENTINEL, we set up sensors in different parts of the country," Curry explains,

Photos courtesy of Chronos.

"to look for instances of jamming. One of the sites we chose was a certain UK-based telco rooftop in London, specifically the one above Keybridge House in Vauxhall. This is a high building, 15-stories tall, and important, what a major UK-based telco called an 'international gateway,' a key node in their network."

Very quickly, researchers monitoring the sensor atop the building noticed a lot of interference. What was causing it? It's still hard to say, says Curry.

"The cause could have been a line-of-sight, microwave radio link, just traversing that roof space. Most likely this would be coming from a tall building nearby, and there are plenty of those to choose from in London. It would actually most probably be a harmonic effect, a radio link with a harmonic that would sit on top of a GPS signal." Beyond that, he says, there's just no telling.

"In the meantime, we'd heard about a new anti-jamming antenna," Curry says, "and we thought it might be interesting to give it a try, as long as we were up there and with a regular pattern of interference to test it against."

UP ON THE ROOFTOP

"I met Peter Soar at some conference or other and we got to talking," Curry recalls. Soar is NovAtel's Business Development Manager, Military & Defense, based in the UK. "And then we met again, more than once, on similar occasions."

And, it would seem, they found common ground. "I knew Chronos Technology were specialists in Position, Navigation and Timing [PNT]," Soar says, "with an emphasis on timing, mainly based on GNSS and eLoran. As such they were also experts in mitigation against GNSS interference and timing."

Now aware of Chronos' activities on London's rooftops, Soar decided to join the show.

"Chronos had been in contact with NovAtel's UK Dealer, Forsberg Services Limited," Soar says. "Understanding their desire to investigate further the interference they were seeing, we agreed to provide a GAJT to Chronos, on loan, via Forsberg."

GAJT on top of Keybridge House in Central London prior to building demolition.

Chronos Technology Ltd. delivers critical timing and synchronization services to the heavyweights of Britain's telecom industry. But the company has also carried out some heavyweight research, demonstrating the vulnerability of GNSS-based timing and proving the worth of a leading-edge anti-jamming system by NovAtel.

POSTSCRIPT: A FALCON'S TALE

Built between 1976 and 1978, Keybridge House on London's Lambeth Road had been described as one of the last hurrahs of the modernist architectural style in London.

Although not designed specifically as a housing block, it had, over the years, become irresistible as a place to live for at least one pair of London's celebrated Peregrine falcons, a very special, rare and officially protected species.

So out of bounds are these delightful creatures that when one such couple of soon-to-be parents sets down for a spell, as they did atop the Keybridge House in the middle of the SENTINEL experiment, no one is allowed to go anywhere near them, meaning the project, with all installed equipment, had to be abandoned until the birds were well and done and the little ones had flown the coop.

"By February, it was too late to get on the roof," says Curry. "The nesting Peregrine is protected by law, so we couldn't get back up there until July."

"The presence of the birds meant that our GAJT could not be removed for some months," says Soar, "although the trial was initially supposed to last only for a few weeks." However, he adds, the antenna remained working and protecting GNSS signals throughout. So the fine, feathered, and very happy couple had in fact helped researchers to prove not only the power of the GAJT but also its durability and longevity.

Alas, none of them will be coming back again, neither the birds nor the researchers. In the summer of 2014, after the chicks had flown the nest and the SENTINEL node had been dismantled, Keybridge House was demolished. With a major UK-based telco relocating and the venerable old building beyond refurbishing, city planners had given the OK for the place to be put to rest, permanently.

HOW IT WORKS

NovAtel's website says, "GAJT, pronounced 'gad-get,' is the first single-unit GPS anti-jam antenna appropriate for use with military land vehicles, networks, and timing infrastructure."

A high-powered gadget indeed, specifically intended for military use, but its particular characteristics make it useful to almost anyone with a jamming problem. GAJT is an externally mounted unit, requiring only power and a single RF cable. No additional electronics are necessary.

The GAJT product line is a result of close co-operation between Defense Research and Development Canada (DRDC) and NovAtel, combining DRDC's Electronic Warfare expertise with NovAtel's GNSS signal processing and product development heritage.

"Throughout the development of GAJT," Soar says, "we have sought the optimal mixture of performance, size, and cost. The latest development, our 'Space Frequency Adaptive Processing' (SFAP) algorithm, gives a step-change in performance inside the same form factors. Also, by enabling analysis actions like 'freezing the weights' of the system to allow for detailed evaluation, NovAtel has enabled user organisations to perform their own tests to verify our claims."

GAJT's proprietary technology is a null-forming system that protects the GPS receiver, simultaneously on L1 and L2 frequencies. It passes through the good GPS signals and ignores the jammers by steering nulls in the antenna gain pattern towards those jammers. This means that GAJT only passes good GPS signals to the receiver which is once again clear to operate normally."

"The first GAJTs used Space Time Adaptive Processing (STAP), in common with other anti-jam systems on the market," Soar says, "but our GAJTs now use the improved SFAP algorithm: digital processing includes a Fast Fourier Transform (FFT) process to separate the incoming signal into a set number of equal frequency bins, followed by parallel space/time calculations in the form of a Least Mean Square (LMS) power minimization algorithm on each of those frequency bins, and finally an inverse FFT to reconstruct the frequency bands."

THE SPECIFIC BENEFITS OF SFAP ARE:

- NARROW-BAND JAMMERS ARE SELECTIVELY NULLED. SFAP nulls by both frequency and direction of arrival. Narrow-band interference is selectively nulled without attenuating other signals arriving from the same direction.
- BETTER PERFORMANCE VERSUS WIDE-BAND JAMMERS. Compared to STAP-only anti-jam systems, the SFAP algorithm is less sensitive to input filter phase variations and can accommodate edge-of-band group delay variations, allowing for improved performance in the presence of wide-band interferers.
- STEP-CHANGE IN PERFORMANCE: Coverage Improvement Factor (CIF). These changes

together show a marked improvement in CIF, the method used to assess and compare the performance of Controlled Radiation Pattern Antennas (CRPAs) of various geometries and numbers of elements. GAJT can now excise jammer signals that are very close geometrically to the wanted GPS signal, giving unmatched anti-jam performance, Soar says.

The SFAP algorithm can also operate in modes at different sensitivities.

"The choice of mode allows for the trade-off between sensitivity in excising the jammer and fixed latency through the system," Soar explains. "This is particularly helpful when selecting a GAJT configuration for use with helicopters, as the block mode can be adjusted to take into account the frequency of the helicopter's rotors."

Without that adjustment, he says, chopped reflections of jammer signals can disrupt the nulling.

Crucially, for Chronos, by selecting a mode with appropriately low latency, protection of timing subsystems can also be facilitated.

SUCCESS

Soar says Chronos Technology installed and operated the GAJT without the need for any support. The GAJT was mounted on the roof in place of the existing standard antenna and provided with a DC power connection. When it was attached to the timing server's GPS receiver via the existing RF cable, it started to provide protection immediately.

"GAJT was designed for armoured vehicles but it clearly works well for timing server installations as well," Soar stated.

"GAJT worked, and it worked well. The interference stopped. We simply fitted the antenna, and it worked perfectly," Curry says.

"While we have focused mainly on serving defence and military customers," says Soar, "GAJT is also applicable to any GPS installation, as Chronos Technology has demonstrated. The security services and critical infrastructure such as cell phone networks and financial systems are all in need of protection from jamming."

"The biggest user of GPS-based timing and sync today is telecoms," Curry says, "especially CDMA mobile networks which are not generally deployed in the UK and EU. GPS-based timing could become more popular over the next couple of years as new services are launched to manage the demand for more bandwidth.

So, while Chronos, with the SENTINEL project, had initially set out to look for instances of jamming, it also provided a good demonstration of a promising interference mitigation solution, allowing us all to be more confident that those increasingly present jammers and other sources of interference will not ultimately negate the wide-ranging benefits of GNSS technology. ▲

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Keybridge House, location of Chronos's interference investigations, has since been demolished and is to be re-developed as seen in artist rendering.