Rohde & Schwarz is one of several companies producing mobile HF COMINT systems, including these truck-mounted ensembles believed to be in service with a Middle Eastern customer. (Photo: Rohde & Schwarz)

RADIO RENAISSANCE

Of all the COMINT tasks the EW practitioner must perform, detecting and exploiting HF skywave transmissions are among the most vexing. As there has been renewed interest in HF radio in recent decades, HF COMINT systems are on the rise.

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On 27 October, the New Zealand Defence Force (NZDF) advised amateur radio enthusiasts they would lose access to two frequencies: 5.353MHz and 5.362MHz. The NZDF's decision reflects the growing importance of HF in military communications, something which is having an impact on the COMINT community.

Renewed interest

From its first use in 1923 for communications, and until its slow demise with the advent of SATCOM in the 1960s, HF radio was considered vital by air, land and sea forces. Yet the last two decades have seen HF garner renewed interest.

SATCOM, which largely superseded HF, can be expensive and vulnerable. A nation must design, launch and operate a sovereign SATCOM capability. This comes with a price tag of billions of dollars. Nations unwilling or unable to afford this must lease bandwidth, which has a cost. Communications satellites are also at risk from the anti-satellite surface-to-air missiles which are being developed, and have been tested, by China, India, Russia and the US.

Concurrently, the last ten years have seen improvements in HF radio performance. While physics prevents HF transmissions carrying the volumes of data hauled by SATCOM, data rates of 120kbit/s are now possible. Along with improving the quality of HF voice communications compared to legacy systems, this allows imagery and video files to be handled with comparative ease.

Skywave communications

HF radio inhabits the 3-30MHz segment of the electromagnetic spectrum. It has an attribute not largely shared by its radio brethren in higher bandwidths: HF transmissions can traverse intercontinental distances. In contrast, VHF and UHF radio works best for point-to-point transmissions uninterrupted by obstacles like buildings, high terrain and even the curvature of the Earth.

HF achieves these impressive ranges because HF transmissions cannot penetrate the ionosphere, an atmospheric layer at altitudes of between 60km and 1,000km. Ultraviolet radiation from the sun hits electrically neutral gas atoms in the ionosphere. This radiation causes electrons to detach from the gas atom, although these free electrons are kept in place by Earth’s magnetic field. The free electrons refract HF signals transmitted into the ionosphere back towards the ground. This allows HF communications to reach intercontinental ranges. Transmitting HF signals in this way is known as skywave communications.

△ HF COMINT systems are outfitting UAVs. This VStar Systems' MA-C MiniPOD being one example. (Image: VStar Systems)

A variant of HF skywave is called Near-Vertical Incidence Skywave (NVIS) communications. NVIS still uses the ionosphere but does so to communicate over much shorter distances, which normally could be achieved using line-of-sight (LoS) V/UHF communications, but which are blocked by a physical obstacle these frequencies cannot penetrate.

We can think of troops in a mountain valley who need to reach their HQ in another valley on the opposite side of the rugged terrain. They angle their HF transmissions to zoom up steeply to hit the ionosphere, causing them to be refracted into the valley on the other side of the mountain. If one throws a ball upwards at a steep angle, it will only land a short distance away. Throw the ball at a shallow angle and it will still go upwards, avoiding obstacles, but travel further. This summarises the difference between NVIS and skywave transmissions.

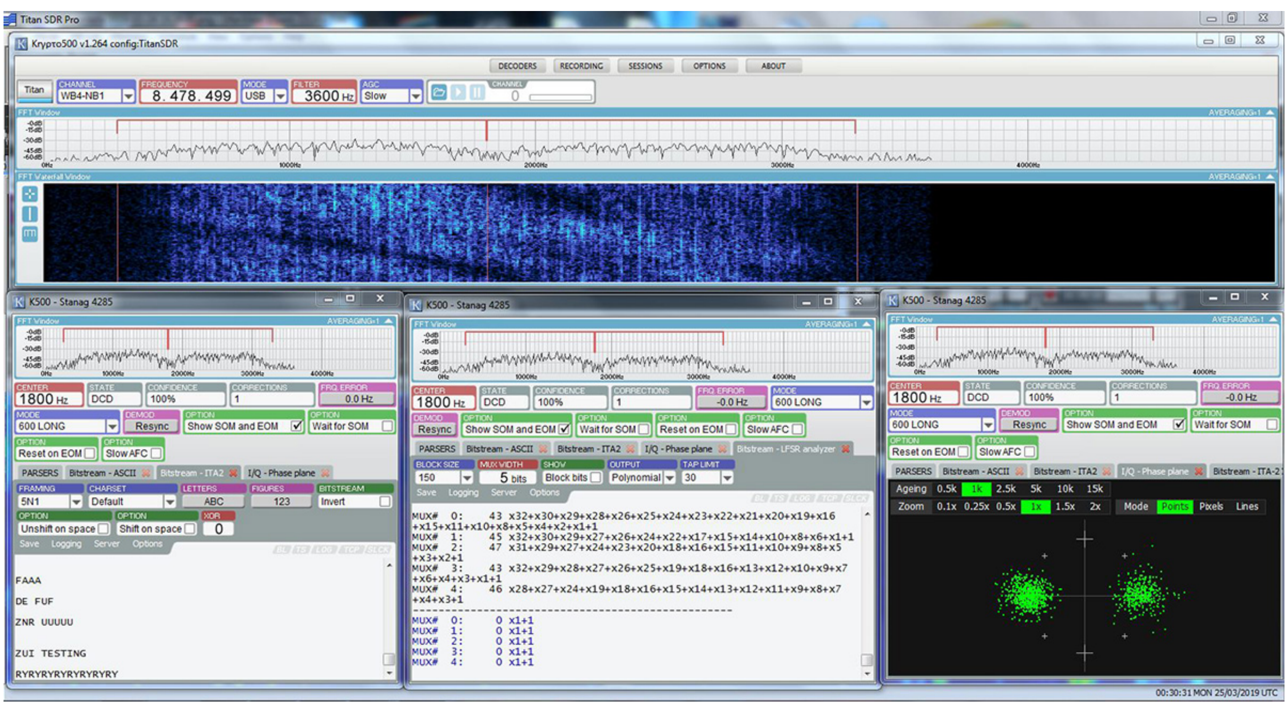
HF headache

HF's properties are good for signallers but create nightmares for COMINT practitioners. The first problem is the ionosphere. This has a 'dynamic and unpredictable nature', according to Dr Peter Barker, lecturer in communications and communications EW at Cranfield University, in the UK. The ionosphere reacts to phenomena like solar flares, which can have a serious effect on its ionisation levels.

Although software helps to predict which frequencies are best for skywave use at a particular location in any given moment, operator skill is still required to understand how the capricious ionosphere might behave.

Knowing where to position your HF antenna to intercept the HF transmissions of interest is another consideration. There is a distance between the HF transmitting radio and the receiving set. In HF jargon, this is known as the 'skip zone'. According to Jim Kilgallen, president of COMINT Consulting, both NVIS and skywave present challenges: 'Skywave and NVIS can be challenging for intercept operations by a COMINT system due to incorrect or less-than-optimal positioning.'

The problem is that you need to get the HF receiving antenna you are using to collect the COMINT in exactly the right place. There is a danger that the HF antenna can be in the skip zone, or that it might be outside the radius where the reflected signal reaches the Earth: 'In both cases, this can be at worst a completely missed target signal, or at best, marginal or inadequate signal-to-noise ratio (SNR).'



△ A screenshot of COMINT Consulting's HF COMINT software. The programme can run several processes simultaneously to expediate signals analysis. (Image: COMINT Consulting)

For skywave, COMINT practitioners have a trick up their sleeve. They can exploit the groundwave transmission which accompanies its skywave counterpart. Groundwave is a phenomenon by which HF signals follow the curvature of the Earth as they are transmitted. This is distinct from LoS transmissions which beam in a straight line from one transmitter to a receiver. Groundwave transmissions hug the Earth's surface as they radiate from the transmitter. This is analogous to the Coandă Effect which can be observed as fluid sticking to the exterior surface of a glass as it is poured slowly.

The efficiency of groundwave transmissions depends on the connectivity of the ground and the frequency of the transmitted signal. It is not always practical to use groundwave for long-distance communications. One exception is ship-to-shore HF communications where the sea's salinity provides good conductivity. Nonetheless, by getting an HF antenna close to the transmitting skywave antenna, it may be possible to exploit accompanying groundwave transmissions for COMINT. Likewise, it is necessary to get a receiving antenna close enough to the radio receiving the NVIS transmissions. In both cases, this could be risky. Kilgallen said that one option is to use clandestine, remote, unattended sensors. These can be placed and left, reducing the risk of COMINT personnel being discovered.

Waveform challenges

Another challenge is the sheer quantity of HF waveforms available. The waveform determines the frequencies to be used, whether the traffic is to be encrypted or clear, whether it will carry voice or data and, in HF's case, whether the transmission will use groundwave, skywave or LoS propagation.

For the COMINT professional, the challenge is that 'there are currently 3,000 different waveforms active in HF communications', Kilgallen noted. 'Furthermore, there are several new waveforms appearing each and every month.'

COMINT Consulting produces its RadioID software which helps make sense of this muddle. It can extract an array of information from an HF transmission, including information on the make and model of the modem the radio is using for its transmissions and the signal's parameters. The RadioID now has 55 decoders which can demodulate and decode HF transmissions.

Demodulation plays an important role in COMINT. Radio signals are modulated. Modulation forms part of the transmission waveform where a bearer signal is overlaid onto a carrier signal for transmission. This is analogous to a train. The bearer signal can essentially be seen as the people and goods carried by the train and the carrier signal as the train's carriages. Demodulation extracts the goods (bearer signal) from the train (carrier signal). This is important as the bearer signal contains the voice or data traffic being transmitted by the radio.

Putting matters into perspective, Kilgallen said that there are several hundred waveforms which use a form of modulation known as 8PSK at rates of 2,400bit/s. If an HF COMINT system can only recognise the 8PSK modulation, it may only be able to tell its user that there are several hundred targets in range of the COMINT system's antenna using this modulation, but nothing more. Much more information still needs to be extracted from such a transmission to be useful.

△ HF radios are much less cumbersome than in the past. This has helped deepen their appeal, although the proliferation of such devices increases the workload for COMINT practitioners. (Photo: author)

Kilgallen believes that this is something that AI could assist. Barker agrees, noting the contribution that the technology can make concerning signal detection and recognition, as does a written statement supplied to *Shephard* by Rohde & Schwarz (R&S). The company sees a role for AI in signal detection and classification, and to help the processing of HF COMINT delivered from multiple sensors distributed across the battlefield. Similarly, machine learning will help HF COMINT systems improve the precision with which HF radios can be located.

Given that AI is based on algorithms which can learn from previous experiences and from data with which they are fed, AI-enabled COMINT systems could be 'taught' to perform a range of analytical processes when detecting an HF transmission using 8PSK modulation, for example. This could enable the COMINT system to extract as much relevant information as possible. Given the sheer number of HF waveforms in use, which are only likely to increase in the future, the collection of HF COMINT in a specific area, such as a theatre of operations, could become so labour-intensive that AI will be vital to ensuring that the workload of COMINT practitioners becomes manageable.

'Only via in-depth analysis can a fuller picture be obtained and a determination made as to the intelligence value of a given target,' Kilgallen said.

Above all, HF COMINT practitioners should be able to adapt their systems according to their needs at a particular moment, says R&S's statement. Open architecture is necessary to allow the easy integration of decoders and demodulators, the statement continues. Importantly, the operator should be able to easily define the parameters of a particular HF COMINT mission and how incoming signals should be treated. Echoing Kilgallen's thoughts on waveforms, R&S warns that because of the 'immense number of signals, it is not recommended to process all detected signals'.

Making the most

The renaissance of interest in HF radio, as it is being dubbed, has led to a corresponding proliferation of HF COMINT systems. This is not only being seen in the military sector, but also in the homeland security and law enforcement domains where people smugglers, pirates and those involved in illegal fishing may use HF systems to manage their activities.

R&S argues that future HF COMINT systems will need to embrace increasing levels of automation to further improve probability of signal interception, radio classification and location, transmission demodulation and decoding and the recording of raw and relevant HF COMINT. As the world wakes up to neglected attributes of HF, so the COMINT community will need to keep its skills and capabilities sharp to exploit this rediscovered medium.

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