High Frequency Surface Wave Radars: Countermeasures Needed?

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Editor's note: *The author published an expanded version of this article in the September digital supplement of the Microwave Journal. This version focuses more explicitly on countermeasures against HFSWR systems.*

Over-the-Horizon High Frequency Surface Wave Radars (HFSWR) are appearing along the coast of the People's Republic of China and on their artificial islands in the South China Sea. As part of an integrated Anti-Access/Area Denial (A2AD) scheme, these radars are thought to be capable of detecting and tracking surface vessels well beyond 300 km, aircraft above and below the horizon, ballistic missiles, and cruise missiles, with near-targeting-quality azimuth and range accuracy. Robust countermeasures are needed, since they also have the capability to detect and track "stealth" platforms due to their long High Frequency (HF) wavelengths.

HFSWR takes advantage of the conductivity of salt water, which enables a vertically polarized wave in the HF domain (3-30 MHz) to propagate along the curvature of the ocean surface for hundreds of kilometers. US experiments at the Naval Research Laboratory, as well as the US Air Force's TOP SEA radar developed by Sanders Associates (now BAE Systems), proved the concept in the 1960s and 1970s. China's interest in HFSWR began in the 1960s. Today, countries such as China, Canada, and Russia, and other countries operate HFSWR systems for 200-nmi Exclusive Economic Zone (EEZ) surveillance (see Figure 1) and, in some cases as part of their air and maritime defense networks.

HFSWR shore installations are relatively large compared to microwave radars due to the long wavelength in the HF band and the need for a wide receiver array for bearing accuracy. At 1,500 meters wide, Russia's coastal surveillance Podsolnukh or "Sunflower"[1] HFSWR system (shown in Figure 2) illustrates the size; it can track targets out to 500 km. It is advertised as providing counter-stealth performance and is deployed in multiple locations, such as the Caspian Sea, the Sea of Japan and the Sea of Okhotsk. It is offered for international sales as the Podsolnukh-E export variant, which has reportedly been exported to China[2].

Unlike HF over-the-horizon backscatter (OTH-B) radars, sounders are not needed because HFSWR does not depend on the ionosphere. But many of the challenges, such as naturally occurring external noise, man-made interference, and the need for high-subclutter visibility, are shared between these two distinct types of HF radars.

Canada is a leader in monitoring ships in its EEZ via HFSWR. Maerospace (Waterloo, Ontario, Canada) has developed a fourth-generation HFSWR with 120-degree azimuthal coverage up to 200 nm. Their radar—PASE (Persistent Active Surveillance of the EEZ) operates from 3 to 5 MHz and is approximately 650 m in length, as seen in Figure 3. Maerospace's HFSWR is representative of the technology available today.

The dual-use military potential of commercially available HFSWR systems cannot be overlooked. Since 1967, China has developed HFSWRs, which have been

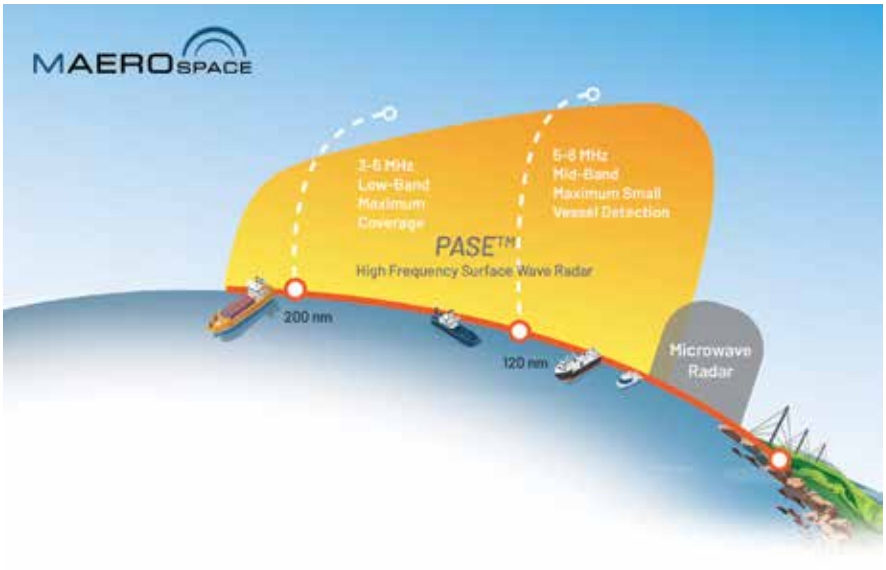

Figure 1: **HFSWR performance relative to conventional radars.** | MAEROSPACE CORP. IMAGE

Figure 2: **The Russian Podsolnukh (Sunflower) HFSWR is a large (1.5-km wide) shore-based HFSWR system featuring separate transmit (left) and receive (right) arrays that are usually positioned at least 1 km apart.** | ROSOBORONEXPORT PHOTOS

deployed at multiple sites along its coast and among the Spratly islands, as well as its "man-made islands" in the South China Sea.[3] It is apparent from open literature that HFSWR is part of their A2AD scheme. Extensive Chinese academic literature demonstrates a long-term commitment to developing and deploying HFSWR.

A key advantage of HF is that target scattering is typically in the Rayleigh and Mie (Resonance) regions, because the wavelength of the radar is larger or nearly equal to the target. Reducing radar cross section via shaping and radar absorbing materials become less effective, making HFSWR an attractive means of A2AD coastal surveillance.

From an EW perspective, however, surface wave propagation is quite lossy compared to LOS propagation, which provides an inherent opportunity for electronic attack systems. Sea clutter, sea state, external noise, man-made interference (e.g., shortwave radio) and other factors will degrade HFSWR detection range. Useful range and Doppler information in the presence of interference also limit radar waveform choices. A modern HFSWR is likely to place a high-dynamic-range digital receiver at every antenna element, to the degree affordable, for simultaneous digital beamforming and adaptive nulling of interference and jamming. A coherent integration time interval is needed to pull moving targets out of the ocean clutter.

Constant-false-alarm-rate (CFAR) processing and target tracking pose significant challenges for the HF radar designer. HFSWR proliferation and open literature speaks volumes for three intelligence needs: a constant OSINT effort; frequent ELINT collection; and theoretical analysis of likely wartime modes. Frequent collection of adversary HFSWR signals will build an understanding of how these systems operate over time and various conditions in the electromagnetic operational environment.

Since sites are large and their locations fixed, Destruction of Enemy Air Defenses (DEAD) using conventionally guided weapons is an option for defeating HFSWR transmitter elements. (The Podsolnukh system, for example, is usually configured with one transmitter comprising two antennas spaced about 20-30 meters apart.) If more than one transmitter array is deployed in a multi-static configuration, however, this would be more challenging to destroy, especially when considering that the receiver array can comprise 30–

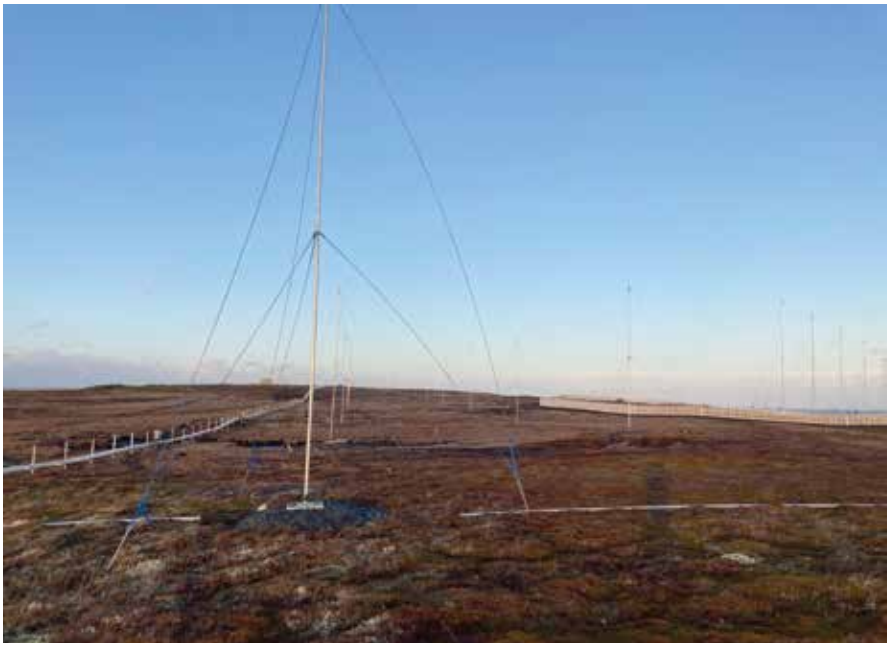

Figure 3: **The PASE HFSWR installation on Cape Race, Newfoundland.**

MAEROSPACE CORP. PHOTO

HFSWRs are fixed-site installations located right at the shoreline. From a countermeasures perspective, USVs and UUVs, such as the Manta Ray (above) developed by DARPA and Northrop Grumman, can maneuver very close to the victim radar and activate their jamming payloads. | NORTHROP GRUMMAN IMAGE

50 (or more) antennas spread across a site that's usually at least 1.5 km wide. How many weapons are required to take the array down, and how long will it take an adversary to reconstitute it?

Early warning radars are ideal candidates for denial via tactical deception and jamming rather than destruction. Deploying decoys against an HFSWR may lead an adversary to make bad decisions, which might be better than simply blinding their sensor. The degree to which this is possible needs analysis, but history suggests there might be a number of electronic attack schemes that can be employed to deny, degrade, and deceive HFSWR systems.

Another consideration for the ECM designer is the radar's digital adaptive beamforming. The HFSWR may have many degrees of spatial freedom, but some will be needed to null interference, such as skywave noise and HF communications overlapping with the wideband radar waveform. Digital beamforming is a potent ECCM feature, but it can also become a vulnerability if the available degrees of freedom can be overwhelmed. This might imply jamming close to the radar using multiple sources over an angular sector of interest to protect strike group assets.

High-altitude jamming from EA-18G Growlers or EA-37B Compass Call aircraft would have a distinct LOS propagation advantage, but this is challenging due to the mismatch between optimal HF transmit antenna size and what can be carried on these relatively small platforms. Shipboard HF systems are likely to be adaptable to this mission, providing screening jamming for themselves and the carrier strike group, but this requires those jamming signals to be transmitted from the ships, which might be in emission control (EMCON). However, offboard, non-collocated jammers well in front of the strike group can provide a jamming-to-signal ratio (J/S) advantage given the higher loss of surface wave two-way propagation. The emergence of highly capable UUVs and USVs make this a practical option.

Jamming techniques to be considered range from noise to coherent false targets. The high two-way path loss, the unique HF electromagnetic environment, and complex radar CFAR might make for interesting twists on electronic attack techniques, especially if delivered at ranges much closer to the radar than the air or surface assets we are protecting. Overcoming adaptive beamforming will be a challenge, but an understanding of the actual available spatial degrees of freedom and radar signal processing methodology might yield insights leading to highly flexible ECM techniques to defeat, degrade, or deceive. With modern HF digital transceivers, jammers need not be overly complex and may not need high transmit power to be effective.

Using UUVs and USVs to position the jammers closer to the threat than the aircraft and ships that are being protected is an attractive approach, with the jammers hidden within a vast ocean, popping up an antenna when jamming is needed. A small field of these jammers may be sufficient to overwhelm the radar at an affordable cost relative to the assets being protected, such as a carrier strike group.

HFSWR technology is mature, available, and being deployed by Russia and China as part of their respective A2AD strategies. HFSWR poses an inherently counter-LO, early warning and target acquisition threat, and countermeasures must be developed and deployed to the warfighter. It is time to pursue these countermeasures as part of a counter-C5ISRT strategy.

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