History is replete with attempts to find applications for High Frequency (HF) radar – military as well as environmental. Starting from the billion dollar Air Force behemoths with 10km antennas that died with the end of the Cold War, the company COS picked up the pieces to carve out a viable niche market and product: the SeaSonde. Based on simplicity and compactness, this low-powered coastal radar is used for mapping surface currents, monitoring sea state and dual-use ocean surveillance, thus filling a gap in coastal measurement technology.

CODAR Ocean Sensors

After 40 years: commercial success in HF radar

Don Barrick made his first mark with his PhD thesis research into radar, developing methods to assess the moon's surface roughness in preparation for the lunar landings in the late 1960s. This segued from solid planetary surfaces into HF radar scatter from the ocean. The surface roughness is now set to motion as gravity attempts to flatten the wind-blown waves on its liquid interface. Initially, the motivation was detection of military targets like aircraft and missiles. The initial HF work involved both sky-wave radar (where the signals bounce off the ionosphere to reach distances of 4,000km) and surface-wave radar (where signals diffract beyond the visible horizon to ranges from 25 to 300km). The antennas for these first HF radar were huge. As an example, the US Air Force sky-wave systems had phased array antennas spanning more than 10km. When their primary aim of detecting low-flying Soviet bombers evaporated at the end of the Cold War, these were shut down because of their outrageous operating costs. Although this programme never led to cost-effective surveillance, the intense and annoying background 'sea clutter' quickly became our 'signal' of interest. Barrick's first conventional, phased array radar on San Clemente Island in 1970 still required an uncomfortable area of land (500 metres) but demonstrated the ability to measure currents and monitor sea state by harnessing the Doppler shifts.

Company President Don Barrick (right) inspects SeaSonde receive antenna with Pukyoung University technician Mr Dae Hyun Kim

After his initial period with Ohio State University and Battelle Research Institute, Barrick joined the NOAA Wave Propagation Laboratory to develop further the remote sensing of currents and sea state. His goal was to get rid of the huge antennas that were an impediment to commercial, operational use. To do this, he relied on Direction Finding (DF) instead of beam forming. 'CODAR' was coined to define this concept. It led to several patents and awards and seventeen field experiments at NOAA demonstrated its accuracy. NOAA encouraged its CODAR team to commercialise the technology and so, in the mid-1980s, the company CODAR Ocean Sensors, Ltd. (COS) was born in Boulder, Colorado from the NOAA team that invented it.

Company Organisation and Survival

Although venture capital and borrowing money to get off the ground appear attractive to many, COS avoided both of these routes to commercial viability. Such conventional paths typically force a company to forego critical research and product refinement in the thrust to reach oftentimes unreasonable sales and profit estimates. Because of the founders' general experience with radar and echoes from different targets, they initially subsidised their meagre incomes by moving to California's Silicon Valley and contracting their services within the 'stealth' industry.

As the Cold War wound down and stealth research evaporated, key COS staff further tightened their budget and even operated from the garage of one of the founders for six months. This period led to a solid product, the SeaSonde, introduced in 1992.

The atmosphere of the company is unique in that many staff are top experts in HF radar technology. Theory, design, manufacturing, sales and customer support are all conducted in-house. Many staff members have known each other for more than twenty years, although this is changing slightly as the company brings new members into the fold.

All COS stock was originally held by the four founders. As the company grows, it gives stock options to increase incentive among its key employees. Staff benefits include comprehensive medical and dental plans entirely funded by the company, annual bonuses for everyone, and pension/profit-sharing investments by the company averaging 15 per cent per year. These benefits are unheard of in the US, especially in small companies. Throughout the period since 1992 company sales have grown at an annual rate of 30 per cent. Employee retention is almost 100 per cent.

What Does a 'CODAR' Look Like?

CODAR SeaSondes are compact, unobtrusive, low-cost and low maintenance; very important attributes for the crowded coastal locations where these systems must be planted. A complete remote radar includes a transmit and receive antenna, each on single posts, connected to transmitter and receiver chassis and controlled by a desktop/laptop computer for real-time processing. The radar consume less than a kilowatt of power, allowing some even to operate from alternative energy sources at remote, uninhabited coastal locations. All hardware design and assembly has been done by the staff of COS.

Because it operates three orders of magnitude lower in frequency than its microwave cousins, one cannot borrow from that line of components. The technologies are totally different. While this was initially time-consuming, it now enables us to design, build and test new ideas on rapid time-scales.

The hardware you see is not the essence of a SeaSonde; 80 per cent of a SeaSonde is its software, the part you don't see. The company's principals began the software 28 years ago at NOAA, and have been evolving it ever since. Roughly half of the COS staff are involved in software development. In addition to the real-time algorithms, there are diagnostics, calibration tools, data transfer schedulers, displays, oceanographic products like movies, trajectory calculations, tidal analyses, etc. All of these are driven by user-friendly Graphical User Interfaces (GUIs). 'It's all in the software!' is more than an idle expression for HF radar and is most of the reason for the 30-year gestation period.

SeaSonde transmitter and receiver chassis with computer to control and process radar signals

Company Culture and Industry Standard

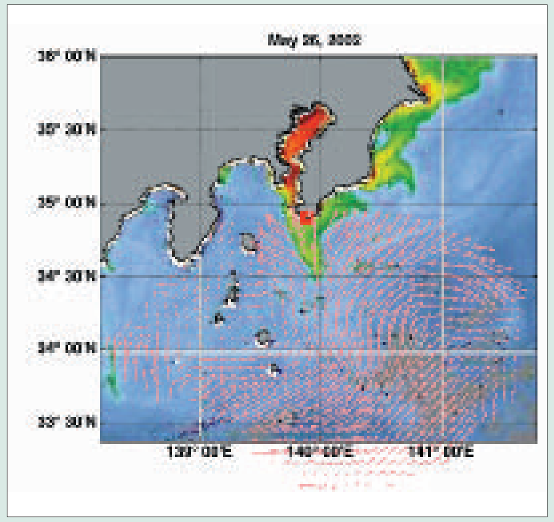
When no one else does what you do, how do you decide what will work? You look to your closest industry relatives, in our case the folks that make acoustic Doppler profilers. They were about twelve years ahead of HF radar in going commercial but their product is sufficiently different to make its culture not entirely match. CODAR is a remote sensing system, with no instrumentation in the water. So you try, fail, get feedback from anyone and everyone, then try again. Patience and longevity have been key. Here's what worked and how we set the industry standard: have modem accessibility to radar, provide clients with free software upgrades, stay focused on a narrow sector of technology and always try to do it better.

All system fabrication is done in-house, including these 6-layer circuit boards each requiring hundreds of solders

There is nothing more frustrating than having your ocean sensor shut down, with a resulting large data gap. The SeaSonde is designed for remote access and control via phone or Internet modem. This remote access allows the user to automatically retrieve near real-time data continuously. It also allows operation of the radar as though standing in front of the computer screen in the field. And, when requested, COS engineers at their offices are able to connect to nearly one hundred radar around the world and quickly get to the bottom of any problem. More often than not, the company can fix it in the software just by dialling in. Many systems have operated for years on end, with 1-2 per cent data outages or less. When the support is this simple, COS offers it at no cost to the client.

As the company learns, improved versions and entirely new software packages emerge. Upgrades are

In Focus



Long-Range SeaSonde surface current data spanning 200km offshore overlain on SeaWIFS data captures complex Kuroshio current as it meanders off the coast of Japan. SeaSonde data courtesy of Tomotaka Ito, Japan Coast Guard. SeaWIFS image courtesy of Dr. Robert Arnone, Naval Research Laboratory

available free of charge to customers who have bought the basic product. The customer is the ultimate beneficiary of a comprehensive upgrade and support policy.
COS is a company dedicated only to the niche market of HF/VHF radar for ocean surface remote sensing. It is not active in microwave – a significantly larger market in which significantly larger companies can do better. Furthermore, COS restricts itself to radar for real-world applications that require compact, low-cost unobtrusive antennas. Having spent decades in multi-million and even billion dollar government programmes where one- and two-of-a-kind radar were tested, the company designs radar that can be afforded by a much wider audience and can fit on a very small amount of real estate.

Crystal Ball Future

Now that the SeaSonde is well crafted into a solid commercial system, the company is shifting R&D towards other products that will expand the applications and market. As the number of SeaSondes soar, separate frequency channels for each have become impossible. In response, the company invented a signal modulation multiplex-ing method that uses GPS as an accurate timing base, thereby allowing dozens of its systems to operate on the same frequency, at the same time and without mutual interference. This invention spurred the use of simple, stand-alone bistatic transmitters to augment existing coastal SeaSondes, extending the coverage and adding multiple observations of the same target cell. Finally, pushing frequency to UHF but using the same DF principles to keep the antenna small, COS is testing a RiverSonde to profile surface velocity across rivers. This promises to improve needed real-time discharge estimates at thousands of sites on streams and rivers, with remote sensing replacing less reliable in-water instrumentation. ■

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