OCTOBER
VOL. 25, NO.10
jedonline.com

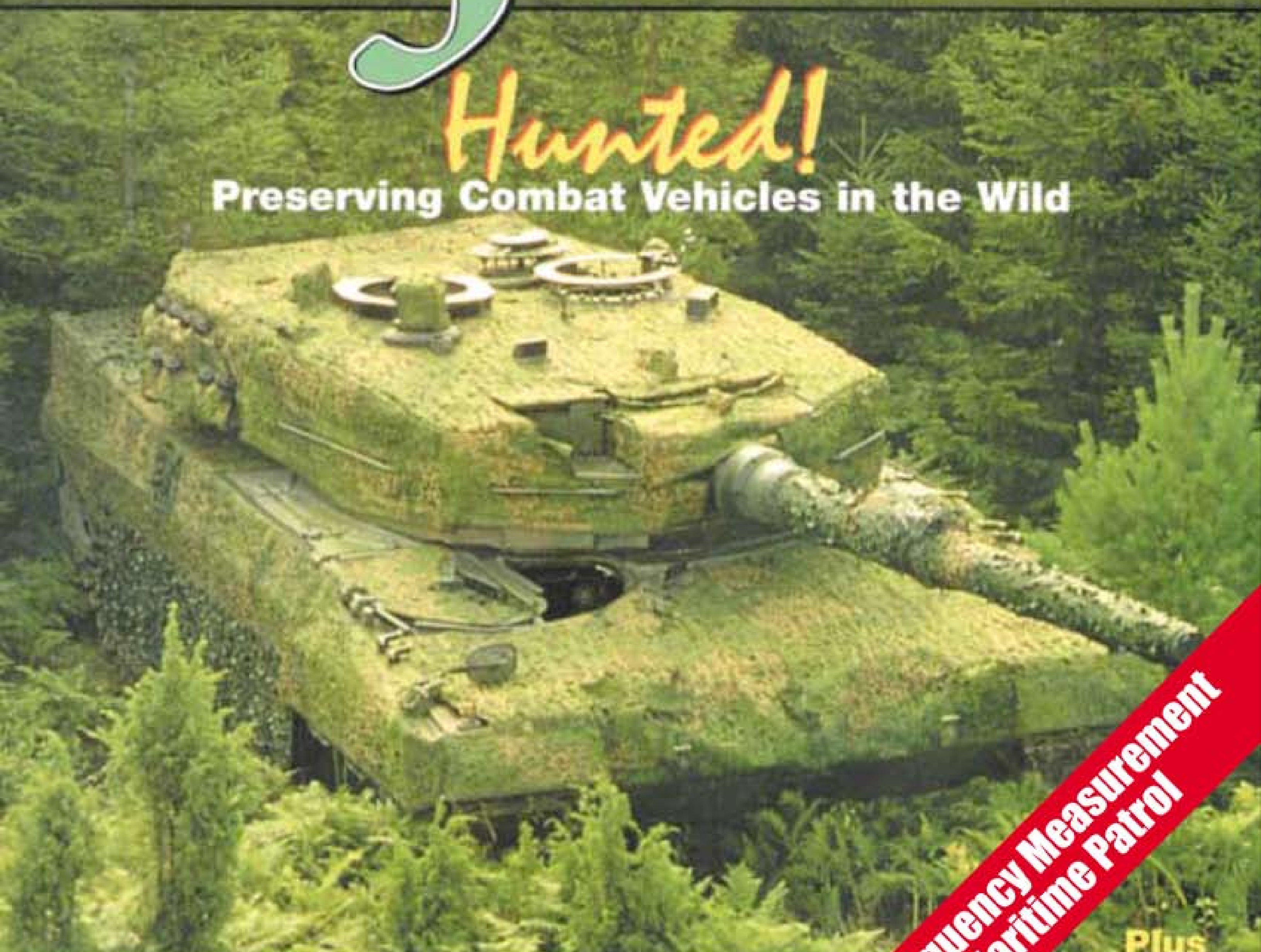
The AOC Electronic Warfare & Information Operations Publication

JED

The Journal of Electronic Defense

Hunted!

Preserving Combat Vehicles in the Wild



Plus

US ing Priorities

Maritime eiver Technology

national Symposium

Instantaneous Frequency Measurement Receivers for Maritime Patrol

horizon

Instantaneous Frequency Measurement Receivers for Maritime Patrol

William B. Sullivan
Wide Band Systems, Inc.

ELINT applications for IFM receivers in EW systems include shipboard intercept and analysis systems such as the AN/WLR-1H(V)7 now being deployed on US Navy CV and CVN vessels as well as Coast Guard WHEC High-Endurance vessels. The Coast Guard is exploring how IFM receivers might play a roll in its 'Deepwater' expansion program, which could see new ship classes, such as the new National Security Cutter pictured here, equipped with the technology.
US Coast Guard artist rendering

An ELINT and EW technology for critical patrol platforms at sea and in the air

The modern Instantaneous Frequency Measurement Receiver (IFM) system has come a long way since the introduction of basic Digital Frequency Discriminator (DFD) technology about 55 years ago. What started out as a simple technique to extract digital RF frequency data over a wide instantaneous bandwidth, mainly for pulsed RF inputs, has evolved into an efficient system for real time encoding of the RF input frequency, amplitude, pulse width, and Time Of Arrival (TOA) for pulsed and CW RF inputs. For this reason, IFM Receivers now are incorporated in most advanced EW systems.

The basic measurement technology for RF frequency encoding is the microwave correlator. This simple device processes an RF input signal by splitting it into two paths, delaying one path with respect to the other, then multiplying the two paths. This produces a video signal output of the form $Sin\ \omega t$, where t is the delay time and ω is the RF input carrier frequency. Introduction of a 90-degree phase shift will produce the video output form $Cos\ \omega t$; usually these two video forms are simultaneously employed and the tan^{-1} of the ratio of the two is then processed to produce the desired RF frequency data.

The DFD correlator output data is periodic over frequency with a period of $1/t$. In order to simultaneously provide a wide instantaneous bandwidth and acceptable frequency accuracy, multiple correlators are employed in parallel, with the shortest correlator RF delay, t, determining the unambiguous RF bandwidth and the longest correlator RF delay setting the frequency measurement accuracy. Early DFD designs employed a 4:1 ratio between correlator RF delay lines, oven stabilized the RF delay lines, and employed sequential decoding of the correlator video outputs. The modern DFD employs 2:1 RF delay line ratios, digitally corrects the output data over temperature, and uses a clocked parallel error correction process to extract RF frequency data at a high rate. In addition, the modern DFD can also detect and flag errors (usually due to simultaneous signals) and provide an instantaneous estimate of the existing RF SNR. DFD internal processing will also support the detection of phase and/or frequency modulation (PMOP/FMOP) within an RF pulse envelope.

How IFM Receivers work

Current IFM receiver technology samples the RF frequency, RF amplitude, and the RF SNR; subsequent digital processing extracts the peak RF amplitude, the RF input frequency time synchronous with the peak RF measurement, the TOA and the RF envelope pulse width. The measurements are qualified by a minimum acceptable RF SNR, estimated every clock cycle. This allows the receiver to automatically adjust to changes in the input SNR, without an integrating noise riding threshold.

The IFM receiver digital processing and serial PDW generation makes it an attractive device for processing the IF output of a superheterodyne receiver. In many ELINT systems, a parallel combination of two IFM receivers and a superheterodyne receiver is employed. One IFM receiver provides instantaneous single band coverage over 2-18GHz, while the superheterodyne receiver, using the second IFM receiver for IF processing, provides high sensitivity precise analysis of selected signals. This combination simultaneously provides a high probability of intercept (HPI) capability with a detailed analysis capability.

The most significant operating advantage of an IFM receiver is also its greatest disadvantage: While it accurately processes the largest RF input signal instantaneously observed, it ignores RF inputs of lesser power that are simultaneously present. In the early development of the IFM receiver, it was not unusual for a simultaneous signal 20dB below the higher-level signal to produce substantial frequency measurement errors. In the modern receiver, little effect is seen for power separations of 8dB and substantial errors are not observed until the separation is less than 3dB; in that event an error flag indicates a probable error.

For the usual form of signal processing computers and the serial nature of the IFM receiver output, processing a serial sequence of RF input signals and generation of a PDW for each event fits well to the serial nature of the digital processor. If the receiver could provide PDWs on two (or more) simultaneous signals, the processing problems would increase geometrically.

The problems for an IFM receiver are in two critical areas: First, the practical sensitivity of a wideband IFM receiver is limited to processing positive RF SNR. For a single band 2-18GHz IFM receiver, the practical sensitivity is approximately -60dBm; for an S-Band IFM receiver the limitation is approximately -70dBm. The second problem results from the processing of the highest level RF input signal instantaneously observed. The presence of a high level CW input will effectively desensitize the receiver. This type of problem is usually countered using YIG tuned or fixed notch filters.

Alternatives to IFM Receivers

With recent substantial advances in computational capabilities, and the investments made over the years in alternative receiver design approaches, the majority of ELINT systems for airborne, shipboard, and mobile applications continue to emphasize the superheterodyne and IFM receiver approaches as the favored receiver designs. However, there are alternatives that should be considered. These include channelized receivers that convert a wide RF bandwidth to a parallel array of frequency selective channels; a compressive receiver that sweeps a wide RF bandwidth at a very high speed then converts the frequency data to time data; the Bragg Cell that propagates an RF signal as an acoustic wave through a crystal, then, with a parallel array of photodetectors, detects a reflected laser; and the digital receiver that directly digitizes RF signals and processes digital samples to extract parametric data.

While the channelized receiver offers inherent capability to resolve and process multiple simultaneous RF inputs over a wide spectrum, it suffers from two problems: high cost and spurious responses. A single high level RF input signal can cause multiple channels (not necessarily adjacent) to respond, presenting the system digital processor with the difficult real time task of sorting out the mess.

The compressive receiver also provides parametric encoding of multiple simultaneous RF inputs, but at the expense of accurate pulse width and RF amplitude processing. Since the RF processing device is usually a bulk acoustic wave compressive filter, there are also some limitations on RF dynamic range, due to filter triple travel.

The Bragg Cell receiver offers the possibility of processing multiple simultaneous RF inputs, with the frequency resolution essentially determined by the number of parallel photodetector devices at the output. Although limited in instantaneous dynamic range to approximately 30dB, multiple Bragg Cell devices can be cascaded to extend the instantaneous dynamic range.

Based on these performance characteristics — as well as clear advantages and disadvantages — there's no doubt that the receiver of the future will be based on direct digital technology, offering the possibility of complete signal characterization over a wide RF bandwidth and over an extended RF dynamic range. At present, however, the available digitization rates and analog resolution restricts this technology to relatively narrow RF bandwidths. As the analog to digital converter conversion rates and number of bits converted continues to increase, this technology should eventually dominate ELINT receiver applications.

Applications for ELINT

With regard to most ELINT applications—especially in the 0.5-18GHz RF band—the superheterodyne and the IFM receiver represent practical, logical, and cost-effective approaches. It is interesting that, in comparison to all competitive designs, neither of these designs provides instantaneous detection and processing of multiple simultaneous RF input signals, although the superheterodyne receiver can sequentially process multiple simultaneous signals and the IFM Receiver can detect the presence of simultaneous signals.

The present technology superheterodyne receiver offers narrow bandwidth (4MHz) processing sensitivity better than -90dBm, over the 500MHz to 18GHz band. Processing sensitivity is that RF input level where the parametric encoding of signal parameters is within specification. This receiver has selectable instantaneous bandwidths up to 1000MHz, and can tune in less than 10µS. The time to tune is important, as when the receiver steps across the selected band, the longer the time to tune, the higher percentage of time the receiver is not available for signal processing. An important requirement for a modern superheterodyne receiver is the ability to support single emitter identification (SEI) processing; this places particular stress on the receiver oscillator and synthesizer phase noise characteristics.

IFM receivers are produced in a wide variety of instantaneous bandwidths, including 50-500MHz, 750-1250MHz, 500MHz-2GHz, 2-6GHz, 2-18GHz, etc. Typical RMS frequency measurement accuracy is 0.017 percent of the instantaneous RF bandwidth. The instantaneous dynamic range is typically 70dB, with 0.4dB amplitude resolution. The IFM receiver will process the highest-level input RF signal instantaneously present. Early IFM receivers were prone to frequency measurement errors in the presence of simultaneous RF input signals separated by 20dB; today's IFM receivers accurately process simultaneous RF input signals with power separations less than 8dB, and can flag errors due to simultaneous signals.

There are many highly specialized ELINT applications for IFM receivers in EW systems. These include shipboard intercept and analysis systems such as the AN/WLR-1H(V)7 now being deployed on Navy CV and CVN vessels as well as Coast Guard WHEC High-Endurance vessels. Systems used for these applications employ a single band 2-18GHz IFM receiver to provide a high probability of intercept (POI) in parallel with a synthesized narrow band microwave tuner that provides detailed signal analysis. In this application, the low cost, small size, and serial PDW generation characteristics of the IFM receiver are particularly advantageous.

Another system configuration is even more interesting: that is, use of IFM receivers as primary receivers in threat warning applications such as radar warning receivers aboard manned and unmanned patrol aircraft, an activity that has gained widespread attention in the past year after the events of September 2001.

One major development in conjunction with these activities is the Coast Guard's new Deepwater program. This consists of an approximately $15-billion commitment for "design, engineering, modernizing, and acquiring" systems and platforms during the next two decades. Another $1 billion a year is allocated for operating expenses. A major portion of funding for this program will come from the US Navy, scheduled to procure key Deepwater combat systems, among them EW systems incorporating advanced IFM receivers.

IFM Receivers for Electronic Attack

There's no doubt that IFM receiver-based systems will play a key role in many areas of the Deepwater program. For example, a unique system has recently been developed that provides a high probability of intercept (HPI) electronic surveillance capability for use aboard unmanned aerial vehicles (UAVs) as sensor payloads capable of supporting multiple mission objectives including threat warning, countermeasures cueing, and electronic surveillance. A similar system is also available for manned maritime patrol aircraft (MPA) as well as vertical takeoff and landing unmanned aerial vehicles (VTUAVs).

Advanced IFM receiver technology is ideally suited for UAV electronic surveillance applications for a number of reasons. Specifically, it permits production of lightweight, modular, ruggedized, low power systems that provide all capabilities necessary to safely and successfully accomplish the mission at hand. These systems also provide 100 percent probability of intercept (POI) for emitters from 2-18 GHz; exceptional performance in pulse dense environments; highly accurate direction finding (DF) capabilities, and high system sensitivity which allows for excellent detection ranges.

IFM receiver-based systems for UAVs also offer a wide variety of other advantages including reaction times of less than one second for threat identification, precise RF parametric measurements, and complete programming interfaces for user data files (UDF) and onboard storage for logging all threat emissions. In addition to their use aboard platforms associated with the Deepwater program, they are also capable of being incorporated in unmanned combat air vehicles (UCAVs), where they would also provide virtually real time data for threat determination.

The IFM receiver systems aboard these innovative aircraft provide threat warning as they enter hostile airspace, countermeasures cueing when they engage anti-aircraft threats encountered during a mission, and electronic surveillance to develop precise electronic order of battle data to support parallel missions such as the suppression of enemy air defense (SEAD).

What's even more interesting (from the perspective of practicality and cost-effectiveness), is that systems of this nature are available now based upon existing IFM receiver/ES technology. One key reason for this, is because many system components are commercial off-the-shelf/non-developmental items (COTS/NDI). This ES system technology is field proven and is now in service with the US Navy, Air Force, and Coast Guard. System components are designed for the rigors of the airborne environment, as demonstrated by over 100 Wide Band receivers aboard tactical and reconnaissance aircraft around the world today.

These new ultra-light ES systems for UAVs are expected to find widespread application in the years ahead. Their high reaction time (less than 1 second) and ability to support rapid recognition of threat emissions to permit effective evasive actions or successfully employ countermeasures are critical to mission success. This performance is characterized using simple fixed frequency, fixed pulse width, fixed PRI, non-scanning emitters. These systems are capable of correlating complex emitters (frequency agile, pulse width agile, PRI agile, and scanning).

Successful application of advanced IFM receiver technology for manned and/or unmanned patrol aircraft and surface vessels offers significant advantages to help assure critical mission success at minimal costs, minimal risks, and enhanced security. There's no doubt that as ever more sophisticated (smaller, lighter, and more capable) ELINT/ES platforms are developed, the advancements in IFM receiver technology will keep pace so as to assure a nation's security in an increasingly dangerous world. JED

William B. Sullivan is president of Wide Band Systems Inc., Rockaway, NJ. He may be reached at 973-586-6500; email: bilsul037@earthlink.net.