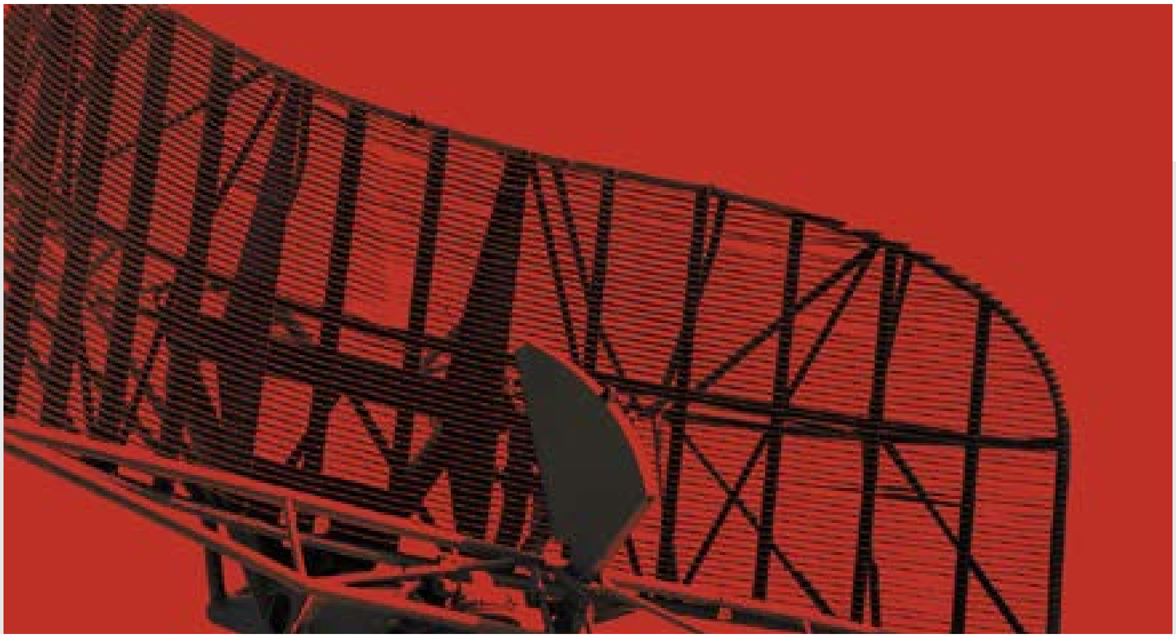
TECHNICAL BRIEF

Modular Test Approaches for SSR Signal Analysis in IFF Applications



Military radar applications call for highly specialized test equipment

Radar signal analysis applications require highly specialized test equipment to model and test transmitted or received signals. Secondary surveillance radar is a type of radar that is often used for air traffic control (ATC) applications as well as identify friend or foe (IFF) military applications. For these applications custom RF test racks are assembled for the specialty testing performed on this equipment. Unlike the interrogators and transponders, or the product used in the field, the test racks themselves are not limited by size or military specifications, but by accessibility and modularity.

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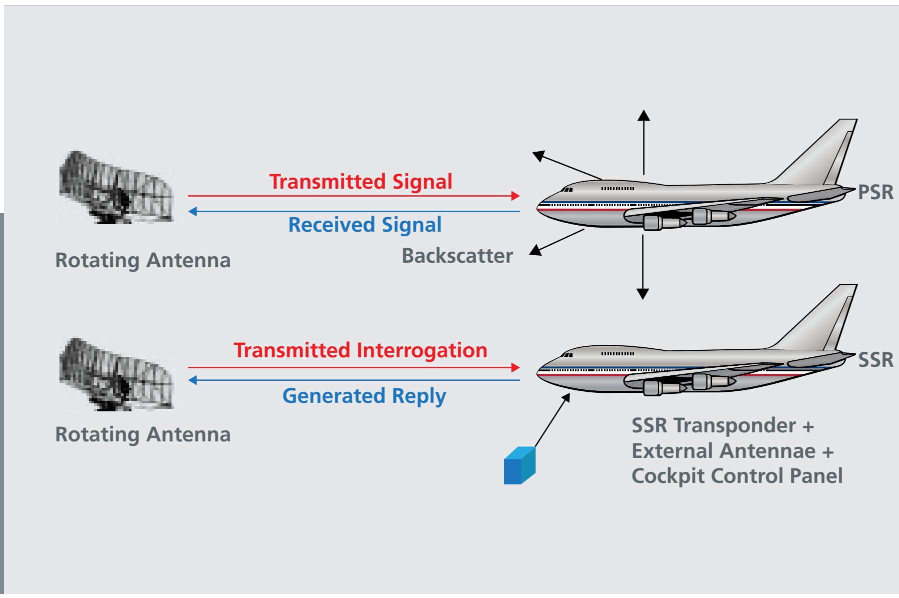


PSR leverages passive replies to generate positional information of an aircraft. SSR uses active replies to not only measure positional information of an aircraft but to also request additional information such as identity.

SSR differs in that the receiver actively generates answer signals where the radar unit both transmits and receives high-frequency impulses.

Secondary Surveillance Radar

Radio Detection and Ranging or radar, very basically consists of a transmitter and receiver that are leveraged to detect the presence of an object through the measurements of range and angle. Primary surveillance radar (PSR) transmits high-frequency signals that reflect at the target. The received signals contain echoes of the original emitted signal this way the ground station is able to determine the location of the target with the "passive echoes" it receives. Secondary surveillance radar (SSR) differs in that the receiver actively generates answer signals where the radar unit both transmits and receives high-frequency impulses.

Currently, SSR systems are employed in air traffic control radar beacon systems (ATCRBS), traffic collision avoidance systems (TCAS), as well as in military electronic warfare (EW) support applications as identification friend or foe (IFF) technology where an aircraft is fitted with a "transponder" (transmitting responder) to send responses back to the ground-based "interrogator" with a coded reply signal. By necessity, this technology employs secondary radar as it requires a coded high-frequency transmit and response signal. The coded interrogation and reply signals operate in different modes depending upon the level of detail required in the response signals, commercial applications include modes A, B, C, D, and S where the military modes have the numerical designations from 1 to 5. In IFF applications, the ground station emits interrogation pulses at 1030 MHz and the transponder sends replies at 1090 MHz. The three-dimensional position is generally broken down from three coordinates: the range (distance), azimuth (direction or bearing), and the altitude (elevation). This request for information such as the position is encoded in the interrogation signal, the method for sending encoded interrogation signals out to a target is through the 'monopulse' technique.

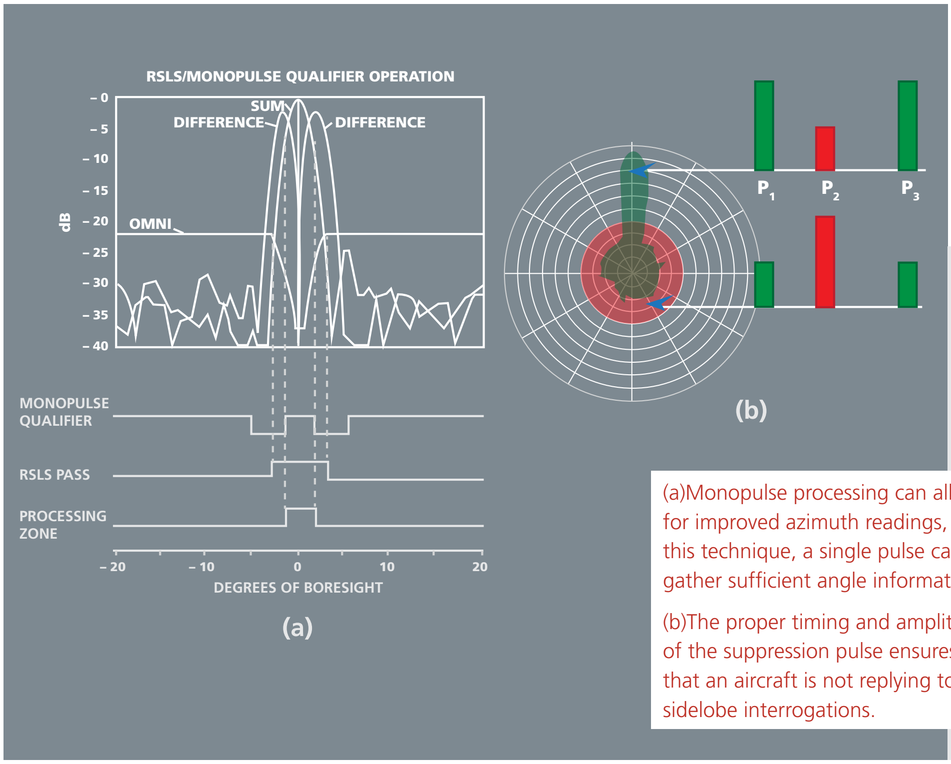
Monopulse & Interrogation Sidelobe Suppression

In the monopulse method, the direction of the radiation of an antenna is represented through lobes, one directional antenna will give off a main beam, while multiple directional antennas can send a pulse simultaneously and give off multiple lobes of radiated energy. The beams then generate hybrid junctions or "sum" and "difference" patterns. By comparing relative strengths of the pulses, a transponder can gauge if the signal comes from the "main" lobe or "side" lobe. The first reply is received when the leading edge of the rotating antenna is noted, as the antenna continues, more replies are received.

In IFF, monopulse is typically leveraged for interrogation path side lobe suppression (ISLS) where the main beam establishes two interrogation pulses (P1 and P3) while the ISLS system inserts another 'suppression pulse' (P2). Typically P1 and P3 have pulse widths of 0.8us and are spaced 3us ,5 us, or 8us apart depending on the interrogation mode. The suppression pulse (P2) is spaced 2us after the leading edge of P1 and must be at least 9 dB below the amplitude of P1.

Ground Interrogation Equipment

The ground station often consists of the PSR directional antenna and SSR omnidirectional antenna. The omnidirectional antenna is grouped as left and right antenna where each side connects to an RF switch to channel energy via a hybrid junction. The hybrid junction distributes the energy equally through to the radiators in the two sections of the antenna that combines/splits the signals into "sum" and "difference" channels to send and receive pulses despite noise caused by the environment/weather. The SSR antenna is normally mounted to the larger PSR antenna to point in the same direction as both antennas rotate to send out interrogation pulses.



(a)Monopulse processing can allow for improved azimuth readings, with this technique, a single pulse can gather sufficient angle information.

(b)The proper timing and amplitude of the suppression pulse ensures that an aircraft is not replying to sidelobe interrogations.

Aircraft Transponder Equipment

The aircraft is outfitted with several antennas to detect and send active pulses back to the ground station. While the antenna placement depends on the type of aircraft, it is generally essential for the antenna patterns to provide enough coverage to be able to send and receive interrogations while doing maneuvers. The transponder is accessed via a console in the pilot's control panel to communicate with interrogations coming from the ground station.

Interrogation Modes

The military interrogation modes have dramatically evolved over the decades with newer stochastic processes and waveform generation techniques. While air traffic control has learned to adopt some legacy modes, the military primarily leverages more modern techniques to ensure secure messaging for IFF applications.

The Mode 1 interrogation signal can elicit 64 various reply codes and is often used in military air traffic control towards determining the type of aircraft flying and what type of mission it is on. Mode 2 includes an identification request with the "tail number" of an aircraft, there are 4096 possible replies for mode 2 interrogations. Mode 3/C replies include information of the altitude of an aircraft by increments of 100 feet is often mixed with mode 3/A to provide a 4-digit octal identification code, this interlacing of modes is known as mode 3 A/C, both modes have 4096 replies. Mode 4 requires both the interrogator and transponder to work with a cryptographic unit to ensure communication with a friendly aircraft. The crypto encodes and decodes signals with long chains of pulses including a preamble to

Sum-Difference Antennas are mounted to the larger Directional Antenna to generate beams that send pulses or coded interrogations.

ensure a secure message, then an ISLS pulse, and finally a message. The crypto itself must be calibrated on a daily basis with several key codes that are valid for only 12 hours. Similar to mode 4, mode 5 is also secured with a crypto to encode an interrogation and reply. Mode 5 leverages modern modulation, coding, and cryptographic techniques to overcome the security limitation of the legacy modes.

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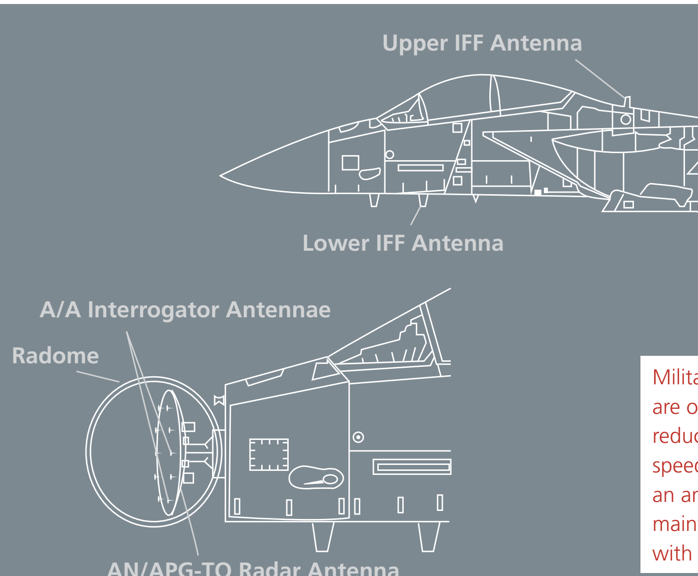


Military aircraft antenna are optimally designed to reduce drag at high speeds while upholding an antenna pattern to maintain communication with the interrogator.

Mode S, or mode ‘select’, employs addressed interrogations to reduce redundant replies. For mode S, each target has a unique address, ‘all call’ interrogations elicit replies from all aircraft in the beam while ‘roll call’ interrogations select specific mode S equipped aircraft with a 24 bit address. With 16 million unique permutations, the ground station can call upon a specific aircraft. Under an ‘all-call’ interrogation, ‘lockout’ can be enabled to lock out particular mode S equipped aircrafts so they do not receive the interrogation. These unique identifications for mode S equipped aircraft are used to eliminate false replies unsynchronized in time, or FRUIT. FRUIT often occurs in environments when an aircraft is in the proximity of beams from two or more different interrogators, in this scenario an aircraft can receive transmission from two or more different ground stations causing asynchronous replies, or overlapping replies in time. As the population of air traffic increases, the number of ground stations and transponders increase and

Production/Engineering test & measurement for interrogators/transponders or even general military radar applications can be highly involved with custom RF panels containing components such as mixers, fixed attenuators, digital attenuators, RF switches, phase shifters, potentiometers, etc.

this directly correlates with an increases in FRUIT. SSR techniques such as mode S equipped aircraft and ISLS pulses are implemented to minimize this phenomena.

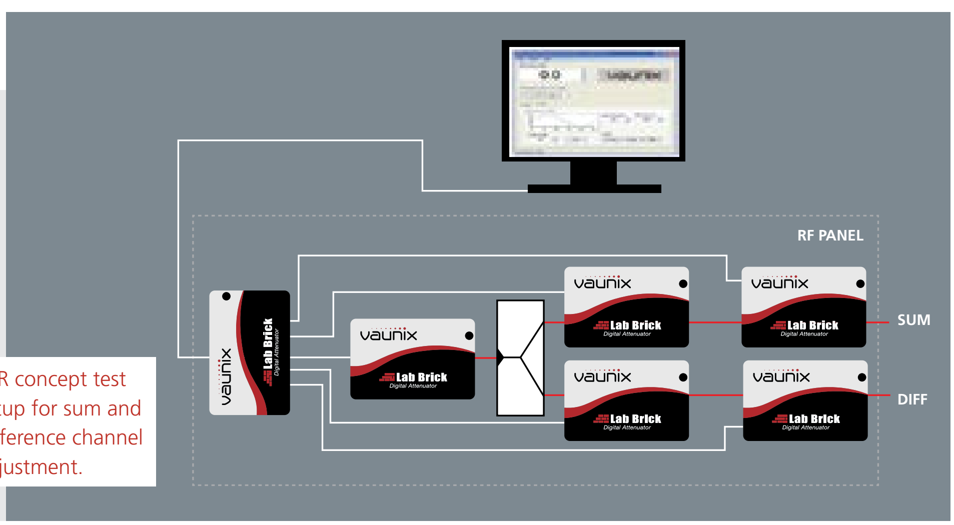
Highly Specialized RF Test Panels

IFF radar signal analysis often requires customized RF test racks for test and measurement of the interrogators and transponders. Along with the updates in fighter aircraft technology come the updates and revisions of their respective RF test systems just to optimize test capabilities. From production test to specialized engineering test, components such as phase shifters, digital attenuators and RF switches that are modular enough for specialized test applications to automated test equipment (ATE) applications can add value to the testing and development process of radar signal analysis.

USB-Driven RF Components

Vaunix, a massachusetts-based test and measurement company, offers USB-driven ‘lab bricks’, or RF test components, to mitigate restrictions due to complexity of generating automated test equipment. With USB-driven phase shifters, digital attenuators, RF switches, and signal generators their small aluminum lab bricks can readily serve as a replacement for components in legacy RF panels.

The LPS-202 model of phase shifters are programmable 0° to 360° with a



SSR concept test setup for sum and difference channel adjustment.

phase resolution of 1° from 1-2 GHz, with the ability to operate in 1030 MHz and 1090 MHz transmission frequencies. The ready-to-use GUI can track and control several connected phase shifters simplifying multiple device set ups, this way the phase can be changed from a computer without opening the up a test panel and manually adjusting a knob to change the phase for sum/difference channel adjustment.

The benefit that comes with USB-controlled RF switches is the elimination of the external DC bias and switching paths from the input to a particular output port by the click of a button as opposed to manually adjusting the TTL control or creating biasing circuitry. Vaunix offers both SPDT as well as SP4T for cascaded switch setups as well as a power handling of 10W for high powered transmissions. These RF switches allow for automated switching between the sum and difference channels in a test setup.

The USB-control can provide a very similar benefit for programmable digital attenuators that are normally TTL controlled with micro-D connectors or by the manual biasing of discrete bits. Vaunix digital attenuators provide step sizes as small at 0.1 dB with a range as large as 120 dB and can be easily programmed for a fixed attenuation value or swept attenuation for dynamic level control.

USB-driven devices can be an effective alternative to traditional methods of biasing TTL controlled components particularly for ATE production test applications where fast throughput and ease-of-test is key. In military systems where information is highly proprietary and even testing systems are specialized, it is essential to have accessibility to modular components that enable automated test so that internal engineers can generate test racks. Vaunix lab bricks provide a strong alternative to current RF test components due to the their small size, cost-effectiveness, and turn-around time—a very good option to join the approved vendor list for the next revision of a test rack.

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"One of the most significant areas of cost and complexity for a fading simulation system is the accurate and flexible control of many digital attenuators. Modular USB-based digital attenuators provide an advantage in cost, configurability, and device reuse not available in traditional box or rack mount test systems. Few companies have the engineering legacy behind USB-based digital attenuators, and have experienced as much success in this market, as Vaunix. Engineers, educators, and technicians trust Vaunix products, as demonstrated by years of repeat business and positive feedback"

Lab Bricks are Available for Immediate Delivery From Stock

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