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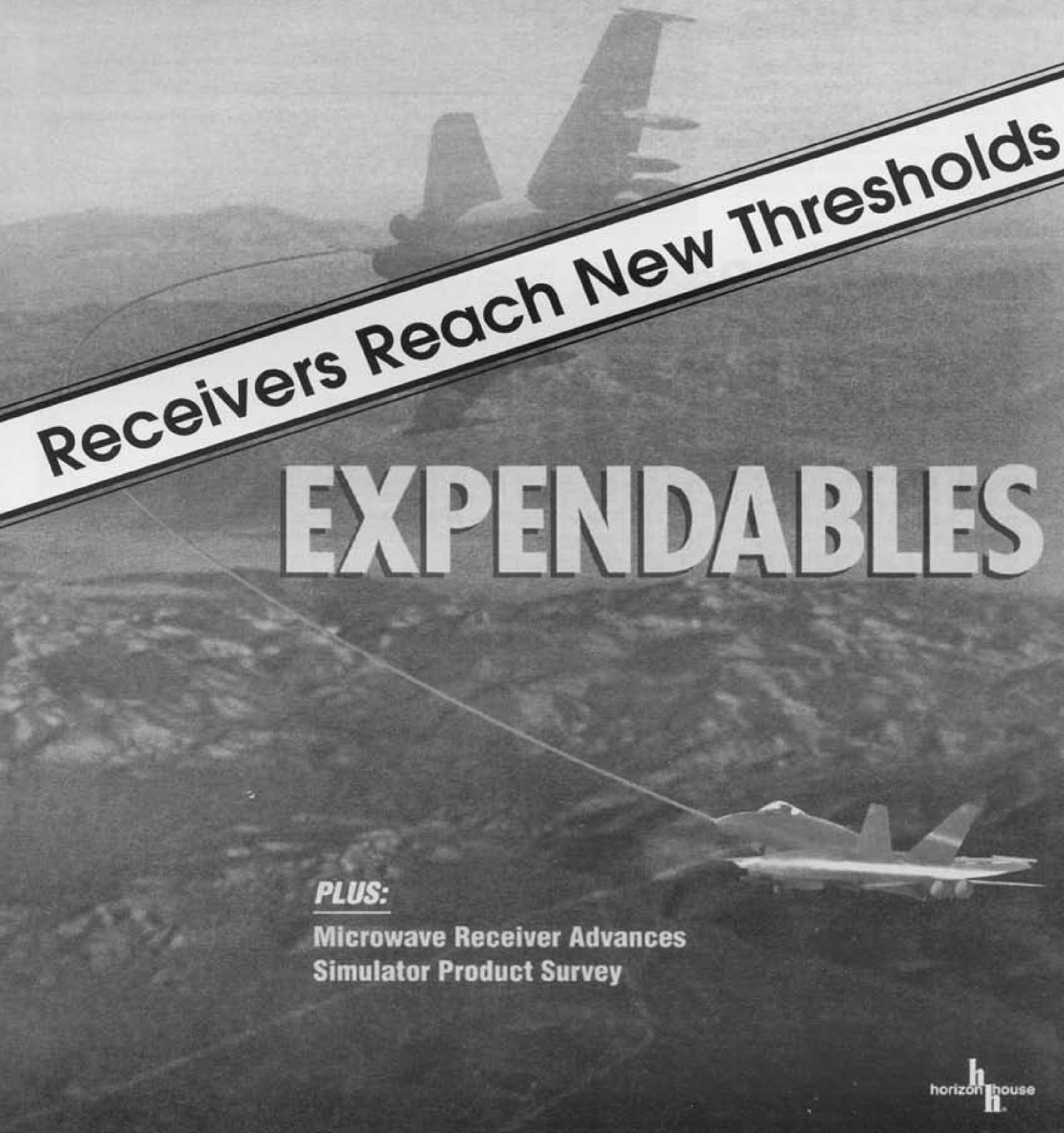

Receivers Reach New Thresholds

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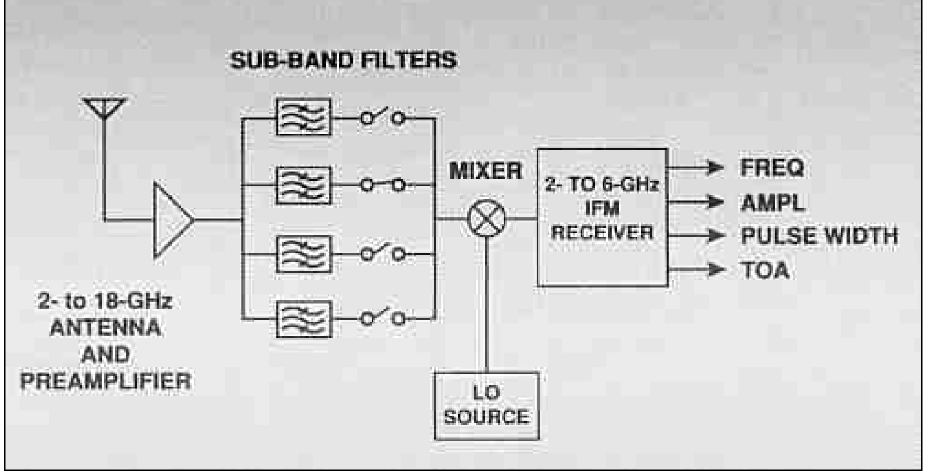

Fig.1 A block diagram of a typical 2- to 18-GHz receiver, converting to a 2- to 6-GHz baseband.

Receivers Reach New Thresholds

William B. Sullivan

As threat environments become more complex, the sensitivity of microwave receivers increases in importance. Sensitivity can be adversely affected by the amount of time a receiver is "blind" while adjusting to signal thresholds encountered during normal operation. While a number of techniques have been developed to accommodate these thresholds, each contains significant drawbacks.

However, a new technique, called "Coherent Threshold," promises to address the problem of quickly adapting to an optimal signal threshold while maintaining receiver sensitivity.

THE PROBLEM

Wide-bandwidth microwave receivers are often employed as part of a variety of radar warning receivers, signal intercept (ESM) receivers and microwave radio direction-finding (emitter location) receiver systems. These receivers, as a consequence of the large instantaneous RF band-widths usually employed, are expected to accurately process a wide variety of signals, including CW signals, short and long RF pulsed signals, high-duty-cycle pulse Doppler signals and other complex waveforms.

A typical system configuration provides antenna and RF preamplifier instantaneous coverage over the 2- to 18-GHz band, then converts this wide band to a narrower base-band for detection and parameter encoding. For example, a system covering 2 to 18 GHz (**Figure 1**) may convert to a 2- to 6-GHz baseband in four RF subbands, rapidly converting each of the RF sub-bands to the fixed baseband to provide a parametric description of the signals present.

A consequence of this system configuration is that the probability of detection of a signal is dependent on both the percentage of time that the receiver is "blind" following a sub-band change and the ability to detect the presence of a threshold (low RF signal-to-noise ratio) signal in the baseband. Because the antenna gain, RF preamplifier gain and RF preamplifier noise figure all exhibit frequency dependence, as do the sub-band mixer and filter losses, we can expect that the baseband signal and noise levels will change following a sub-band change. The receiver system "blind" time is the time interval required to adapt the receiver signal threshold to a change in the baseband signal-to-noise ratio (SNR).

The purpose of accurate signal thresholding is to produce the maximum receiver signal sensitivity that can be achieved, while maintaining an acceptable receiver false alarm rate. Achievement of an accurate signal threshold in the presence of rapid random variations of signal level, signal duration and duty cycle is difficult; the additional requirement to provide this capability while quickly following changes in the base-band RF signal and noise levels as the RF input band is changed makes the problem doubly difficult.

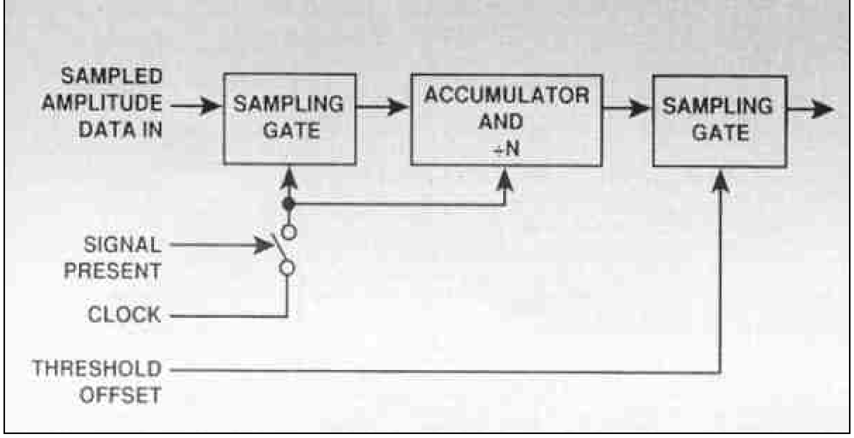

Fig. 2 A logic diagram of a digital noise riding threshold circuit.

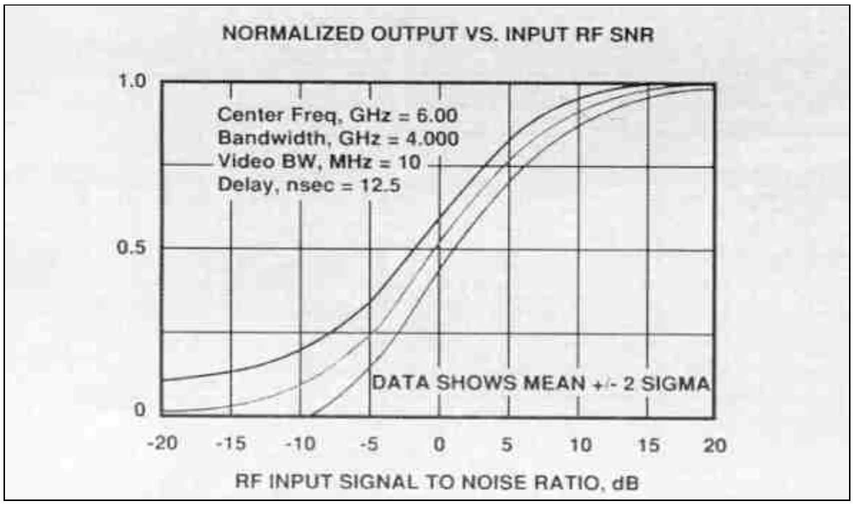

Fig. 3 The normalized output of the coherent threshold estimator for a C-Band baseband DFD.

PREVIOUS SOLUTIONS

Techniques previously employed for establishment of an accurate signal threshold include provision of an operator-adjustable threshold, presetting of the threshold level for each RF band being converted to the baseband or the use of a digital noise riding threshold (DNRT).

Provision of an operator-adjustable threshold is unacceptably slow and often leads to situations where, with misuse, the receiver is desensitized. Presetting a threshold level for each band in an automatic receiver is effective, but — to allow for gain and noise-level variations over frequency, time and temperature — the preset threshold is required to give up a margin of sensitivity in each band. Further, the preset threshold has no capability to ignore external noise, as might be received from a noise jammer. The preset threshold does, however, have the advantage of providing an essentially instantaneous threshold setting following a receiver band change.

The DNRT **(Figure 2)** samples a serial sequence of digital RF amplitude measurements, averaging the noise level present over some period of time (usually 3 msec), then adding a predetermined offset to the average noise level to establish the desired operating RF SNR. The digital output of the DNRT is provided to the receiver as the threshold input, and the receiver will not respond to signals of lesser strength, whether pulse or CW.

In operation, the RF amplitude data input to the DNRT is not sampled during the time that a signal is present to preclude the DNRT from "ramping up" on CW, strong pulsed signals or pulse Doppler signals. Pulse Doppler signals are a particular problem because they usually exhibit a high duty cycle. If the threshold "ramps up," the receiver is desensitized at a time when there is not a strong signal present.

The process of interrupting the sampling process during the presence of a signal is imperfect, particularly for pulsed signals, as it is difficult to prevent some sampling of the leading and falling edges, which are present before and after the signal presence is detected. This is particularly true for slow-rise-time, high-duty-cycle, strong signals. Some desensitization will always occur in practical receivers which use the DNRT.

If a typical integration time of 3 msec is employed in the DNRT, and the DNRT sample timing is not synchronized with the RF band selection process, then the receiver must wait at least 6 msec following a band selection to assure the completion of a complete DNRT integration cycle. If the receiver is operating in a dense signal environment, this waiting period is extended, due to the interruption of sampling during the time of signal presence. If the baseband receiver is switched to a band with a CW signal present, the DNRT may, in fact, never complete an integration cycle.

A COHERENT APPROACH

The Coherent Threshold was developed to provided a fast, automatic threshold which requires no operator intervention. Since it is based on an instantaneous estimate of RF SNR, the Coherent Threshold is not affected by duty cycle or previous RF power levels. The mathematical basis of the Coherent Threshold is based on the estimation of the autocorrelation of the RF signal over a short time interval. For small RF SNR values, the autocorrelation function can be directly related to the instantaneous RF SNR.

Figure 3 provides the theoretical normalized output of the Coherent Threshold as a function of RF SNR, for RF input SNR values ranging over –20 dB to +20 dB. These data are predicted for a C-Band receiver operating over 3.8 GHz to 8.2 GHz. The center curve is the predicted mean value of the estimator; the parallel curves indicate the predicted data spread within plus and minus two standard deviations. Note that the estimator is ineffective for estimating extreme values of RF SNR. For example, a +3-dB RF SNR can be differentiated from a 0-dB RF SNR; a +30-dB RF SNR cannot be differentiated from a +40-dB RF SNR.

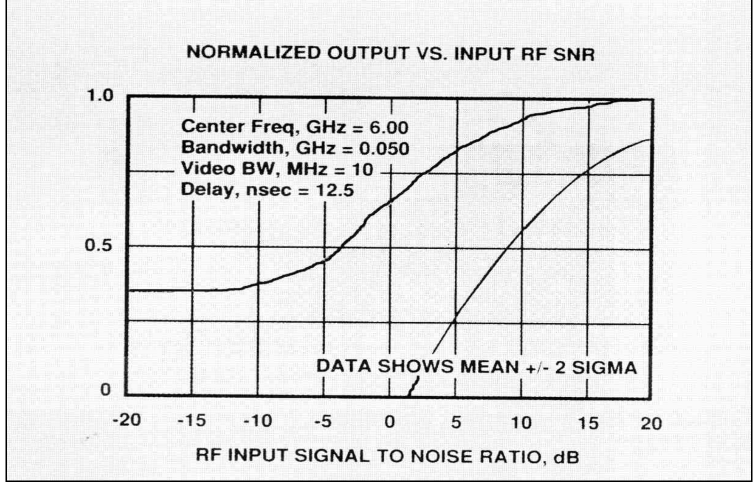

Fig. 4 The normalized output of the Coherent Threshold estimator for a C-Band baseband DFD employing a 50-MHz preselecting filter.

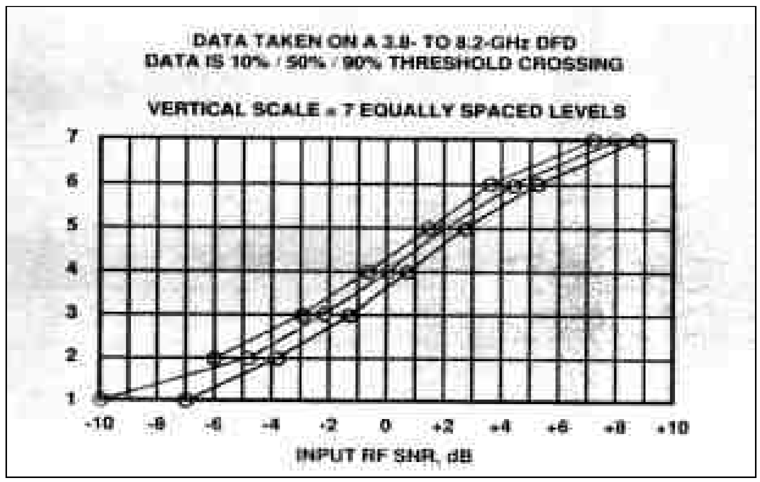

Fig. 5 The measured Coherent Threshold response of a production C-Band baseband DFD, showing the variation of the threshold RF SNR for seven discrete processing levels.

A further limitation in the utility of this estimator lies in the mathematical relationship between the autocorrelation time delay, the video bandwidth and the RF bandwidth. For a fixed video band-width, reducing the RF bandwidth leads to autocorrelation time delays that are too large to provide a useful estimator. **Figure 4** illustrates this effect, where the situation of **Figure 3** has been amended to employ a 50-MHz RF bandwidth. In this case, the upper curve is the mean estimate and the lower curve is the mean minus two standard deviations; the mean plus two standard deviations curve is off scale. The data of **Figure 4** do not describe an effective estimator.

Figure 5 illustrates the operation of this threshold estimator in a production 3.8- to 8.2-GHz digital frequency discriminator (DFD). In this case, an arbitrary linear scale is plotted against the input RF SNR, indicating the threshold limits for 10%, 50% and 90% detection probabilities. The data of **Figure 5** were taken by sweeping a pulsed input over the full DFD band, then adjusting the input RF SNR to provide the desired probability of detection at each of seven equally spaced estimator levels.

APPLICATION

With the limitation, then, of sufficient RF bandwidth and autocorrelation time delay to provide a useful estimate of the RF SNR, the Coherent Threshold has been proven to be a very effective memoryless estimator of small values of RF SNR.

The Coherent Threshold is usually employed in clocked IFM receivers or DFDs, although it could be useful in any receiver application where the autocorrelation of the signal can be estimated. The effect of incorporation of the Coherent Threshold is to provide a receiver threshold which requires neither sampling the actual noise level nor the external estimation of a fixed threshold level. In the clocked IFM receiver and DFD designs, the Coherent Threshold is clocked in parallel with the RF frequency measure-ments at a 40-MHz (one sample per 25 nsec).

To provide an effective threshold hysteresis, two RF SNR values are usually employed. The first, and higher level, RF SNR is used for signal detection; the second, and lower level, RF SNR is then subsequently employed to preclude thres-hold "chatter" on marginal RF SNR input signals. Shifting of threshold values is accomplished in one clock cycle (25 nsec).

Since the Coherent Threshold is memoryless, use of this technique is unaffected by strong, slow-rise-time pulses, pulse Doppler or similar signals which give the DNRT prob-lems. When employed with a wide-baseband receiver, switching of the RF input noise level provides instantaneous receiver availability, without having to wait for an integrating threshold to adjust to the environment. In the presence of broadband external noise, such as from a noise jammer, the receiver instantaneously adjusts to the desired RF SNR, allowing the auto-matic processing of data which are stronger than the external noise and suppressing of false data due to the external noise.■

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