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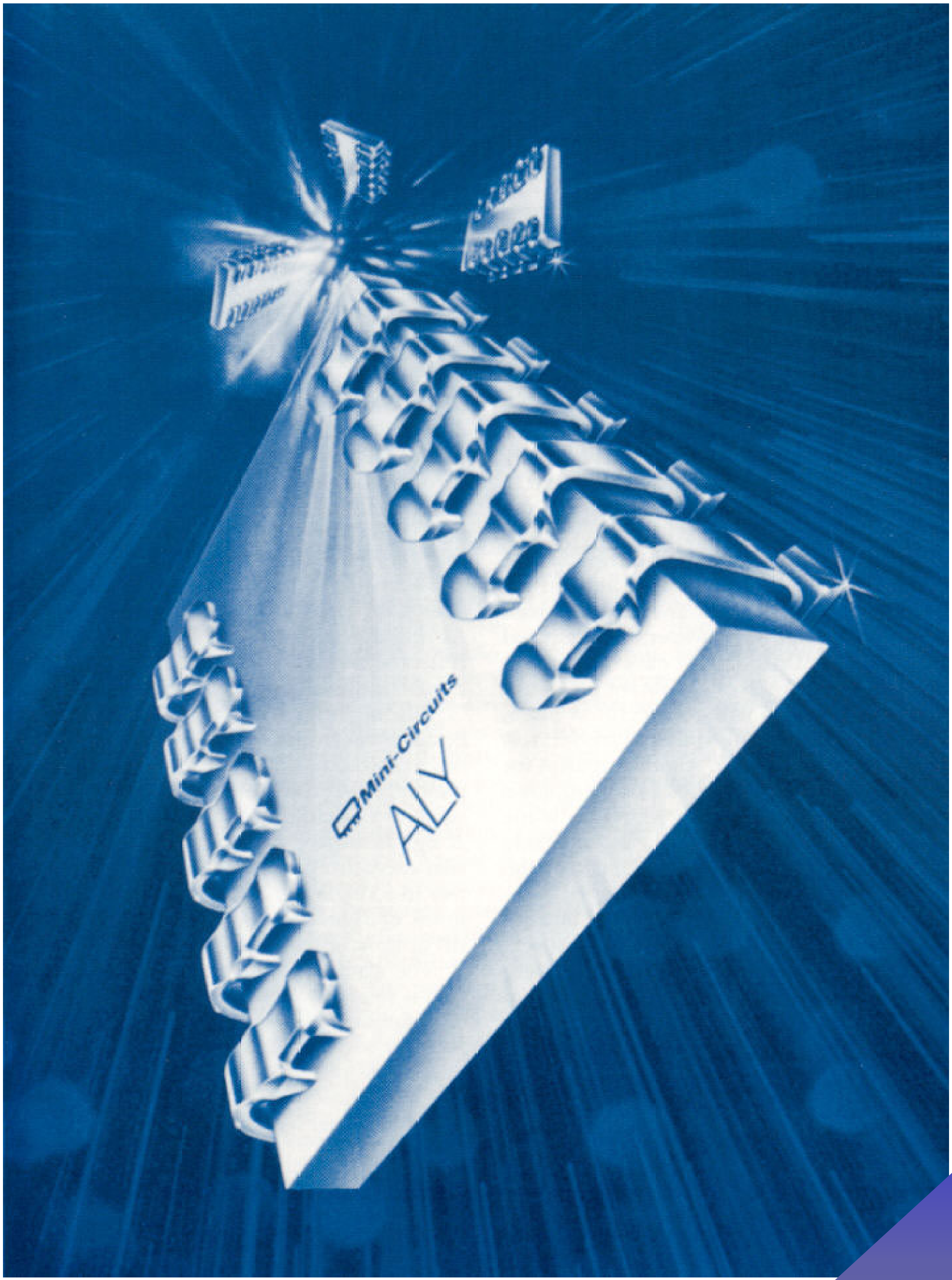


DUAL TECHNOLOGIES AND THE EUROPEAN SUPPLEMENT

BOUNDLESS EUROPE: THE WIRELESS REVOLUTION

OBSERVATION OF A DUAL-USE ROAD WARRIOR

SWEPT MEASUREMENT FOR WIRELESS MATERIAL $\in_r$

Multipath Blanking In Shipboard IFM Receivers

TECHNICAL FEATURE

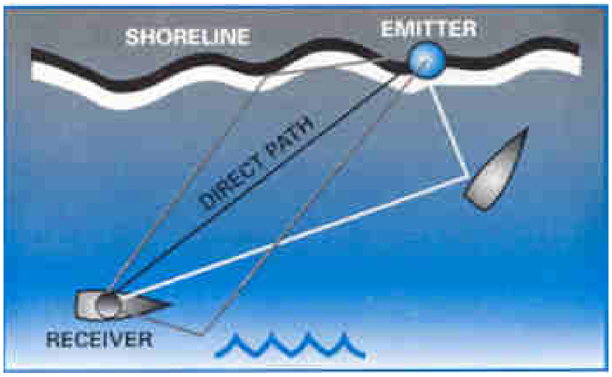
MULTIPATH BLANKING IN SHIPBOARD IFM RECIEVERS

Shipboard electronic support measure/RF collection systems are particularly susceptible to errors due to multipath effects where the receiver observes not only the direct path signal from the emitter, but also signals reflected from the ocean surface or a local land mass. This problem is particularly acute in a littoral environment. ***Figure 1*** shows a few of the common multipath sources.

It is clear that the direct path is the shortest time-delay path between the emitter and receiver. The reflected paths are characterized by longer path lengths. However, the reflected path signal amplitude may exceed the received signal amplitude of the direct path substantially, particularly if the reflector is large, such as a land mass, or specular reflection (glint) from a nearby ship. Another reason for this condition is that the emitter may employ a directional antenna beam pattern and, while the direct path is in the emitter antenna side lobe, the reflected path may originate in the emitter main beam.

The time delay between the direct and received paths may vary from tens of nanoseconds for local sea reflections or reflections from own-ship structures to more than 10 µs for land mass reflections. In a shipboard environment, the multipath characteristics vary slowly because the geometry changes slowly. In general, the received carrier frequency of the multipath signals will be close to the direct path carrier frequency as the slowly changing path lengths cause small Doppler shifts.

▼ *Fig. 1 Common multipath scenarios.*



The effect of multipath is to add coherent, time-delayed, multiple signals following the direct path signal. For land mass and specular reflections, the multipath signal generally approximates the characteristics of the direct path signal in terms of the RF carrier and RF pulse width. For diffuse reflections from the sea, the RF carrier is preserved, but the received reflected signal becomes distributed over time, producing RF envelope stretching. As noted previously, the RF amplitude of the reflected path may vary widely with respect to the RF amplitude of the direct path.

The regions of signal cancellation for two equal-level input signals with varying phase were plotted to determine the effects of multipath on the received signal when the multipath signal is coincident with the direct path signal. A significant region of signal amplitude variation exists from more than +3 to -10 dB relative to a single signal input. In contrast, the regions of signal cancellation greater than -20 dB or greater than -30 dB are relatively small.

The significance of this multipath cancellation is related to the different ways that the instantaneous frequency measurement (IFM) receiver responds to a multipath situation. The amplitude processing circuits will respond to the instantaneous RF amplitude, which, for the equal-level signals, means a high probability of significant RF amplitude variation processing circuits respond

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differently, providing accurate frequency estimates in the presence of multiple RF inputs that are close in frequency as long as the vector sum of the input signals produces a result that is within the receiver dynamic range. For example, as long as the single-signal RF input is more than 20 dB over receiver threshold, then, unless there is more that 20 dB signal cancellation, the frequency processing circuits are not affected substantially by multipath addition. ***Figure 2*** shows the effects of the multipath signal cancellation.

To illustrate the effect of multiple, simultaneous, incoherent, RF inputs into an IFM receiver frequency processing circuit, ***Figure 3*** shows the error pattern for a situation where a fixed signal at -10 dBC and 4 GHz is provided to the receiver input. Simultaneously, a 0 dBc signal is stepped from 3.9 to 4.1 GHz and the receiver error is measured using 10 samples at each step. The plot is the minimum/maximum error envelope. Note that with two incoherent signal sources and as the frequency difference is reduced, the error is also reduced. As a matter of interest, the error envelope on either side of the zero-error point corresponds to the IFM receiver video circuit bandwidth. The essential message is that unless phase cancellation reduces the processed RF signal to an unacceptably low input RF signal-to-noise ratio (SNR), the frequency processor does not make errors in multipath situations.

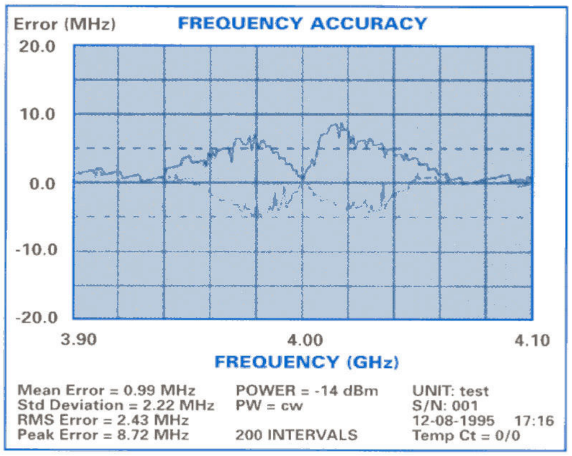


Fig. 3 Simultaneous signal frequency errors.

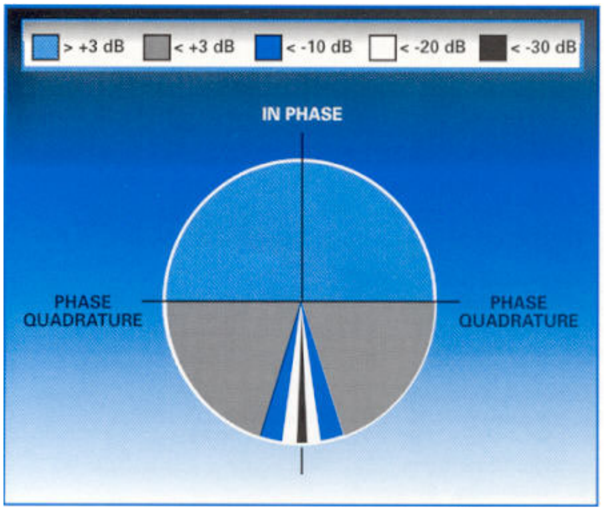


Fig. 2 Multipath cancellation.

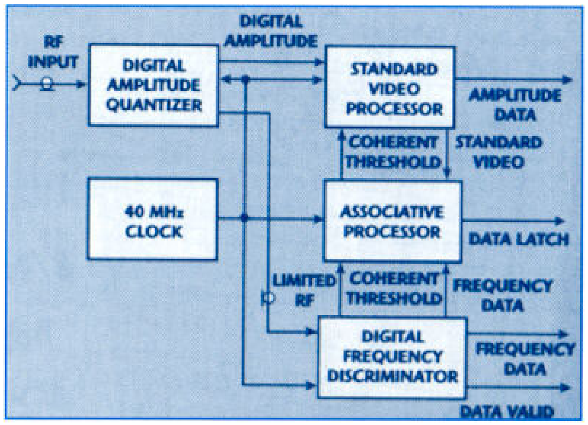


Fig. 4 IFM receiver data flow.

Fig. 5 Standard video processing.

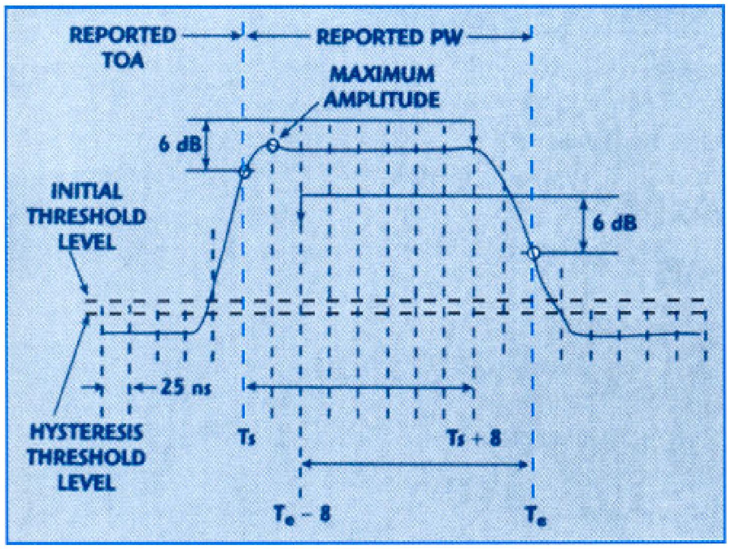
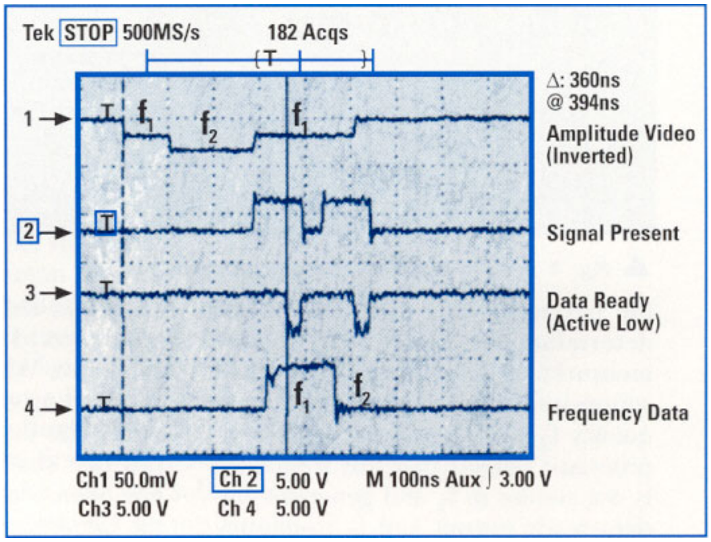


Fig. 6 The associative processor as the leading-edge trigger.



Summarizing the characteristics and effects of multipath, the signal scenario is that of a direct path signal arriving first, followed by one or more reflection path signals. The direct path signals may not be the largest observed signal and, in fact, may be below the receiver threshold. The reflected path signals replicate the general envelope and RF carrier frequency of the direct path signal but, because of diffuse reflections, may appear to distort the transmitted RF pulse width. The time delay between the direct path signal and the reflected path may vary form tens of nanoseconds to more than 10 µs. It is obvious that during this time interval the receiver also may receive RF inputs from unrelated emitters and that each of these may have associated multipath signals.

The receiver RF amplitude processing circuits are likely to produce errors, particularly if the direct and reflected signals are similar in amplitude and the time difference is small (within an RF pulse width). Similarly, the receiver RF processing circuits are substantially less likely to produce error. For multipath events with relative time delays that are greater than the RF pulse width, the receiver observes the multipath as a sequence of RF inputs of varying RF amplitude but approximately constant frequency.

To consider the receiver response to multipath, the way in which the receiver processes measurements must be examined first. Figure 4 shows the basic flow of an IFM receiver. Note that all receiver elements are synchronized by a 40 MHz clock circuit. The monotonic digital amplitude quantizer (MDAQ) provides a serial stream (one sample every 25 ns) of RF amplitude digital data to the standard video processor (SVP) and a limited RF input to the digital frequency discriminator (DFD). The DFD measures the RF, estimates the RF SNR and determines if the frequency data are valid every 25 ns. The determination of an acceptable RF SNR produces the coherent threshold, which is provided both to the associative processor and to the SVP. Frequency data at the 40 MHz clock rate are also provided to the associative processor. The SVP analyzes the series sequence of digitized RF amplitude data to locate the leading and trailing edges of pulsed wave-forms (-6dBc points), generating a standard video waveform, which is a TTL representation of the pulsed signal envelope.

In addition to providing a serial stream of digitized RF envelope data, the MDAQ has the characteristics of recovery from large signals in two clock cycles (50 ns). The SVP analysis technique is shown in ***Figure 5***. Note that the start of the pulse Ts occurs when amplitude samples Ts + 1 through Ts + 8 are less than the amplitude at Ts + 6 dB and the amplitude at Ts is above threshold. The end of the pulse Te occurs when any amplitude sample Te – 1 through Te – 8 is more than the amplitude at Te + 6 dB or the amplitude at Te is below threshhold. The reported amplitude is the largest observed over Ts through Ts+ 8.

In addition to identifying the leading and trailing edges of the RF envelope, the SVP also locates the largest amplitude near the leading edge and latches out this amplitude data with the time-coincident frequency data. The receiver can be operated using only the RF SNR coherent threshold from the DFD or in combination with a programmable threshold. Both thresholds are provided with digital hysteresis.

The associative processor is a digital circuit that determines if two sequential but not necessarily time-contiguous digital words are similar (not necessarily equal). The degree of similarity is designed into the receiver, usually in the range of 0.1 to 0.4 percent of the design unambiguous bandwidth. The associative processor, used in combination with the coherent threshold, provides the DFD with an effective leading-edge trigger capability, as shown in ***Figure 6***.

A larger amplitude short pulse with frequency f_2 is added to a lower amplitude longer pulse at frequency f_1. The DFD employs a limiting RF amplifier. The amplitude video, shown inverted, was detected externally. The

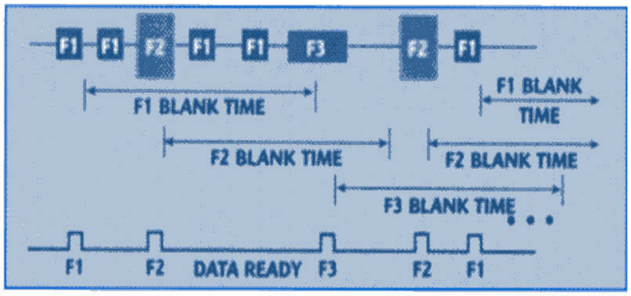


Fig. 7 The associative processor as a multipath blanker.

associative processor is armed by the coherent threshold. The first signal received with an acceptable RF SNR produces a data-ready output with the f_1 frequency data The DFD continues to examine the frequency data every 25 ns, but determines the next few frequency measurements are similar to f_1 and suppresses any response. When frequency f_2 is observed, the associative processor detects that this frequency is not similar to f_1 and generates the data-ready output and f_2 frequency data. The process continues at 25 ns sample intervals. Note that the data-ready output associated with the reoccurrence of f_1 is suppressed since f_1 has been measured previously.

The essential difference between the associative processor as a leading-edge trigger and as a multipath blanker is that, as a leading-edge trigger, the associative processor is armed and cleared by the coherent threshold. In the case of using the associative processor as a multipath blanker, the processor operates continuously using a frequency-dependent clearing capability. ***Figure 7*** shows the operation of the associative processor as a multipath blanker.

The blank time is programmable in the receiver; programming a zero blank time disables the multipath blanker. Although the diagram emphasizes the interpulse multipath blanker operation, the circuit also operates on intrapulse events. For example, if an RF amplitude variation exceeding 6 dB occurs within a pulse, the multipath blanker will suppress the response of the second event providing the RF data are similar and the two events occur within the multipath blanker blank time. The range of programmable blank time is usually from 3 to 30 µs, but must be less than the defined (and programmable) definition for CW (usually 102.4 µs).

In operation, the IFM receiver digitizes the RF amplitude, frequency and SNR continuously. The SVP examines a running sequence of RF amplitude data to locate the –6 dBc points of the RF envelope and the maximum RF amplitude within the pulse near the leading edge. The SVP is enabled by the coherent threshold obtained from the RF SNR estimation. The receiver also may be programmed to employ an additional RF power threshold. The coherent threshold and digitized RF data are also provided to the associative processor. When the SVP has located the leading edge and the maximum value, the associative processor verifies that similar frequency data have not been reported previously within the blank time. If the data are a new event, the RF amplitude and frequency data are latched and the data ready is set. If the frequency data are similar to a previously reported event, the data are not latched and the data ready is not set.

In the presence of CW, this process is modified. At the beginning of a CW event, the sequence is the same as that of a pulsed event. A CW counter is employed to determine the length of the event. When the duration of the event exceeds the programmable CW interval, the receiver sets the CW flag and latches the current frequency and amplitude, setting data ready. As long as the CW signal is present, the receiver will update the output data continuously at the programmed CW interval. The receiver treats the end of the CW event the same as the end of a pulsed event. The essential difference is that the output data are updated at regular intervals using sampled frequency and amplitude data.

In addition to the response described previously, the effect of a CW signal is to raise the receiver threshold for pulsed RF inputs to a level 6 dB above the CW level. The receiver will process these pulsed events normally except that a pulse on CW flag is provided with the pulsed data.

The IFM receiver design performance characteristics can be related to multipath scenarios. The essential characteristic of the IFM receiver, that of processing the largest observed instantaneous signal in the band of interest (which may vary in bandwidth from 50 MHz to 16 GHz), allows higher level direct path signals to be processed in the presence of lower level multipath signals.

The fast recovery time of the MDAQ allows the receiver to receive quickly from own-ship radar emissions, removing the requirements for an external blanking signal to protect the receiver. In addition, this characteristic allows the receiver to operate effectively (with reduced probability of intercept (POI)) in the presence of high level, high duty cycle pulse Doppler signals. The

(Continued)

combination of these first two performance characteristics allows the receiver to process signals in the presence of diffuse sea return from own-ship radar.

The use of the coherent threshold, derived from a sampled estimate of the instantaneous RF SNR, eliminates the problems of threshold ramping, which are common to operation in the presence of high level CW or pulse Doppler signals, using the old digital noise riding threshold circuit approach to threshold setting. The decision as to noise level is made every 25 ns without memory or preceding signal sequences. This threshold also suppresses receiver response to broadband noise jamming.

The SVP analysis technique locates the maximum RF amplitude near the –6 dBc point of a pulse envelope leading edge. This location pushes the RF amplitude and time-coincident frequency measurement away from the leading edge (or threshold crossing) of the pulse while supporting receiver processing of RF pulse widths down to 50 ns (dependent on the RF bandwidth). This technique avoids the problems of older designs that sampled the RF amplitude and frequency for a fixed time following the detection of a threshold crossing. The older technique produces significant measurement errors in the presence of slow rise time RF envelopes or where own-ship reflections caused distortion of the pulse leading edge.

The associative processor suppresses receiver response to subsequent similar frequency data within a programmable blank time. Each distinct RF input frequency starts its own distinct blank time. For the common scenario, where the direct path is above receiver threshold, this technique suppresses all subsequent reports of similar frequency data, effectively removing the multipath events from subsequent processing. Since the blank time is programmable, the host processor can adapt the blank time to the current signal density in real time. Note that the blanking of one frequency does not affect the POI of another frequency.

One common scenario where the receiver provides marginal assistance to multipath processing is when the direct path is located below receiver threshold but a reflected path is located above threshold. The receiver will treat the first received signal as the direct path and any subsequent similar frequencies as multipath. While this process will reduce the data rate to the processor, by eliminating subsequent multipath events, the processor is left with the problem of identifying this report as a multipath report. This identification is usually accomplished by relating frequency and pulse repetition interval in the processor.

The clocked IFM receiver then is understood to provide unique processing solutions to most (but not all) shipboard multipath signal events. In today's high signal density scenarios, suppression of multipath reports by the system receiver allows the host system to processor to become more effective in correct processing of the real environment and retains the high POI capability of the IFM receiver system. ■

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