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Hybridization of Competitive Receivers

Several generic receiver types can be applied to present-day EW receiver requirements: crystal video, TRF (tuned radio frequency) crystal video, IFM (instantaneous frequency measurement), scanning superheterodyne, microscan (compressive), and channelized receivers all have their own advantages and drawbacks.

While each type of receiver is best suited for a particular application, performance demands are forcing designers to consider hybrid approaches which combine normally competitive receiver types. For instance, IFM's are being used to steer superheterodyne receivers, and compact microwave integrated circuits are reducing the size of multichannel superhets. Microprocessor control of housekeeping functions is accelerating development of hybrid receivers and freeing computers for more powerful signal processing to cope with exotic signals.

To meet modern-day requirements, several performance criteria that can be used to evaluate the receiver types for particular applications must be kept in mind. These suggested performance criteria include:

(1) Acquisition: Sensitivity and probability of intercept

(2) False Alarm Rate (FAR)

(3) Sorting parameters: Frequency, pulse width, PRI, scan rate, and exotic parameters

(4) Flexibility: The ability to respond to new threats

(5) Physical characteristics: Size, weight, power consumption, and environmental (shock, vibration, and temperature range).

In addition, to characterize receiver performance, signal types must also be assumed. RF signals will be assumed to include: CW (Doppler), pulse, and exotics (RF diversity, RF agility [interpulse modulation], pulseburst [doublets, triplets, pulse coding], intrapulse modulation [chirp, biphase], and spread spectrum).

Crystal Video Receiver

The crystal video receiver typically consists of an RF bandpass filter, a video detector (square law) and a log video amplifier. Sensitivity may be enhanced by a low-noise RF preamplifier preceeding the video detector, but ultimate sensitivity is limited by the wideband noise power characteristic of broadband crystal video. With broad bandwidth, acquisition time will be short, but sensitivity is low and the false alarm rate may become excessive because of lack of background signal discrimination. Also, while probability of intercept may approach 100% within the passband, no frequency discrimination will occur. Thus, frequency sorting and recognition of frequency modulation is not feasible.

The crystal video radio is relatively inflexible because absence of phase and frequency information prevents discrimination between many signal types. It is easily jammed, particularly by pulse-coincident signals, and key threats can be masked by noise or by stronger signals. There are chopper techniques to allow the crystal video receiver to process CW signals, although jamming by stronger pulsed signals reduces the effectiveness of these techniques.

The RF portion of the crystal receiver is simple, small, lightweight, and consumes little power. The processor may pose difficulties, given that the need for frequency discrimination is an essential sorting parameter. In any given system-level application, the crystal video receiver is often augmented by another receiver technique to provide increased sensitivity and selectivity, such as a scanning superhet channel for frequency discrimination and/or ECM set-on.

TRF Crystal Video Receiver

The TRF crystal video receiver is identical to the crystal video receiver, with the exception of the addition of a tunable YIG filter that serves as a narrowband bandpass filter. Typically, the filter is switched in or out depending on the degree of sorting desired. In this way, frequency sorting is added to the crystal video receivers. However, the presence of phase and frequency modulation will not be detected for the sorting of exotic signals. In the TRF crystal video receiver, POI (probability of intercept) and FAR (false alarm rate) are interchanged as the YIG filter is switched in and out.

The YIG filter adds several pounds, approximately 5 cubic in., and 25 watts of power consumption.

IFM Receiver

The IFM receiver is a type of crystal video receiver configured as a discriminator (see Figure 1). The front end of an IFM receiver has a frequency-sensitive delay which allows a phase shift with a change in frequency, thus providing input frequency information at the output. Typically, the IFM is built in digital form and is preceded by a hard limiter. The digital IFM consists of several parallel discriminators that instantaneously digitize the frequency.

Similar to the crystal video receiver, the IFM is preceded by a preamplifier and can offer probability of intercept approaching 100% within the RF acceptance passband. Sensitivity is limited by the wide receiver noise bandwidth. For stronger signals, acquisition time should be short. Since the IFM provides frequency information with single-signal inputs, sorting of signals where pulses are non-coincident in time is facilitated. The false alarm rate for the IFM will become high if signal environment becomes dense enough to cause a significant number of pulses to overlap. CW, noise, or pulse jamming can also mark lower-level signals.

The IFM receiver is reasonably flexible in that it can process exotic signals that use inter- and intra-pulse frequency modulation, but it is unable to sort out low-level CW signals.

The digital IFM will have RF processing and digitization circuitry that is on the order of ten times the size and weight of the simple crystal video detector. On the other hand, presence of frequency discrimination allows more effective use of sorting parameters, and the processor tasks will thus be simplified.

The IFM is relatively simple in design, the delay lines being the only components that are extremely sensitive to temperature changes. In some designs these are heated to maintain

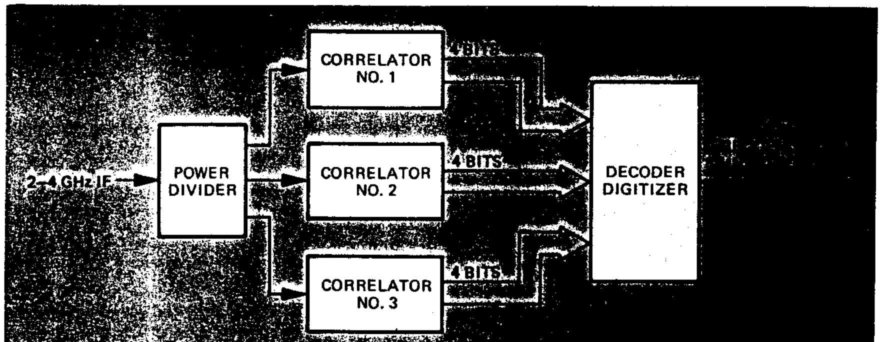


Figure 1. Watkins-Johnson uses a multicorrelator approach to the IFM [illegible] generate a direct digital output in less than 200 nanoseconds for frequency [illegible] tion. A unique error code reduces the crossover error between [illegible] than ±2 MHz.

constant temperature, and thus a significant amount of power may be consumed.

Scanning Superheterodyne

Scanning superheterodyne receivers are typically characterized by high sensitivity, good frequency resolution, and excellent selectivity with the use of preselectors. Thus, the FAR can be quite low, but the POI of a single transmitted pulse will also be low unless fast-scan or smart-scan techniques are used. Fast-scanning techniques are limited by IF filter impulse response and the LO and preselector sweep rates, and normally yield no POI enhancement of microwave frequencies. The smart-scan technique effectively modulates scan rates and limits to optimize POI for anticipated signals of interest. The superheterodyne receiver's high sensitivity often enables detecting side lobe radiation from emitters of interest, thus greatly increasing the POI. Likewise, emitters can often be detected at ranges where broadband techniques cannot pick up a signal. Furthermore, detectability is useless unless it is followed by recognition. The superheterodyne receiver's selectivity allows sorting and identification in a background uncrowded by jamming and other spurious signals, greatly increasing the effectiveness of signal identification algorithms. Typical specifications for a miniature superheterodyne receiver are shown in Figure 2.

The superheterodyne receiver allows a high degree of flexibility in responding to new threat types because it optimizes signal sorting. One disadvantage of conventional scanning superheterodyne receivers, however, is that narrowband types using YIG preselectors do not respond well to exotic signals because of the limited instantaneous RF acceptance bandwidth. This disadvantage has been overcome to a significant extent by the development of a superheterodyne tuner covering the 0.5-18 GHz frequency range, which exhibits several hundred MHz of instantaneous RF acceptance bandwidth. Miniaturization of this tuner with MIC subassemblies paves the way for application to tactical use in ESM (electronic support measures) and advanced radar warning receivers. Projection by Watkins-Johnson Company of small volumes (on the order of 100 cubic inches) and very low (less than 20 W) power consumption for this superheterodyne tuner open the door to many new state-of-the-art applications (see Figure 3).

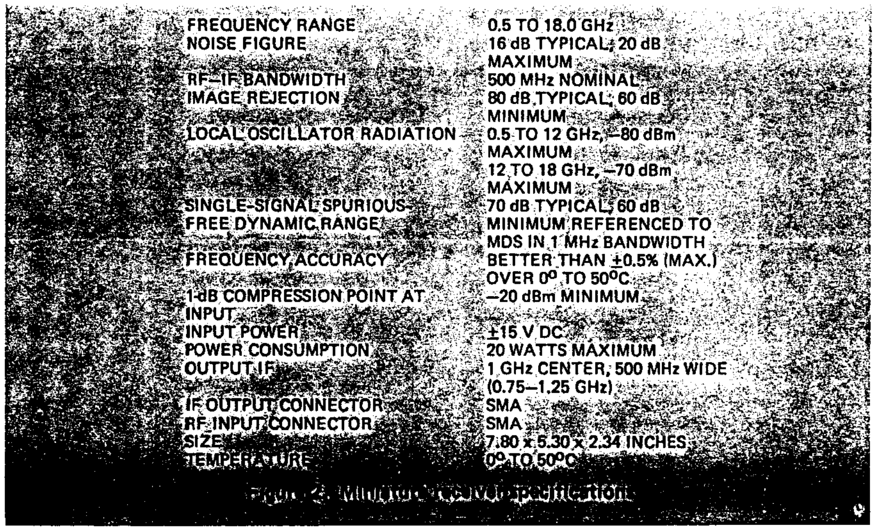
Microscan Receiver

The microscan receiver is a type of superheterodyne receiver that offers high POI for both CW and wide-pulsed signals. The goal for unity POI is to scan the region of interest in a time period less than the shortest pulse to be observed. Unlike the conventional superheterodyne receiver, the microscan (compressive sweep) receiver uses a compressive filter that has a response matched to the scan rate. The output of the compressive filter is a chain of pulses with spacing proportional to the frequency difference. Thus, the acquisition of short pulses dictates a very high output data rate. Sensitivity of this receiver is comparable to a standard superheterodyne receiver, but POI may approach 100%. The FAR will be determined by the effectiveness of the processor in sorting the output of the receiver.

Flexibility of the microscan receiver is limited because pulse width, pulse shape, and exotic parameters are distorted. Size, weight, and power consumption of the microscan RF and IF processing are equivalent to those of a standard superheterodyne receiver. Power consumption and size of the processor are large in comparison with other systems because of the high data rate that must be processed.

Channelized Receivers

Channelized receivers subdivide the RF spectrum of interest and simultaneously down-convert each segment to a common baseband IF (see Figure 4). This is accomplished by using banks of contiguous filters, mixers and fixed-frequency local oscillators. Processing is then done on each of the baseband IF channels that correspond to a segment of the RF spectrum. As the entire RF spectrum is being processed continually, the channelized receiver may approach a POI of unity. Sensitivity of the channelized receiver is high, as with superheterodyne receivers in general. Since all important sorting parameters are maintained, the FAR can be minimized. In flexibility, the channelized receiver is unsurpassed by other types. Its intrinsic drawback is high cost and volume, associated with implementation of many complete receiving channels.



FREQUENCY RANGE	0.5 TO 18.0 GHz
NOISE FIGURE	16 dB TYPICAL; 20 dB MAXIMUM
RF–IF BANDWIDTH	500 MHz NOMINAL
IMAGE REJECTION	80 dB TYPICAL; 60 dB MINIMUM
LOCAL OSCILLATOR RADIATION	0.5 TO 12 GHz, –80 dBm MAXIMUM 12 TO 18 GHz, –70 dBm MAXIMUM
SINGLE-SIGNAL SPURIOUS-FREE DYNAMIC RANGE	70 dB TYPICAL; 60 dB MINIMUM REFERENCED TO MDS IN 1 MHz BANDWIDTH
FREQUENCY ACCURACY	BETTER THAN ±0.5% (MAX.) OVER 0° TO 50°C
1-dB COMPRESSION POINT AT INPUT	–20 dBm MINIMUM
INPUT POWER	±15 V DC
POWER CONSUMPTION	20 WATTS MAXIMUM
OUTPUT IF	1 GHz CENTER, 500 MHz WIDE (0.75–1.25 GHz)
IF OUTPUT CONNECTOR	SMA
RF INPUT CONNECTOR	SMA
SIZE	7.80 x 5.30 x 2.34 INCHES
TEMPERATURE	0° TO 50°C

Figure 2. Miniature receiver specifications

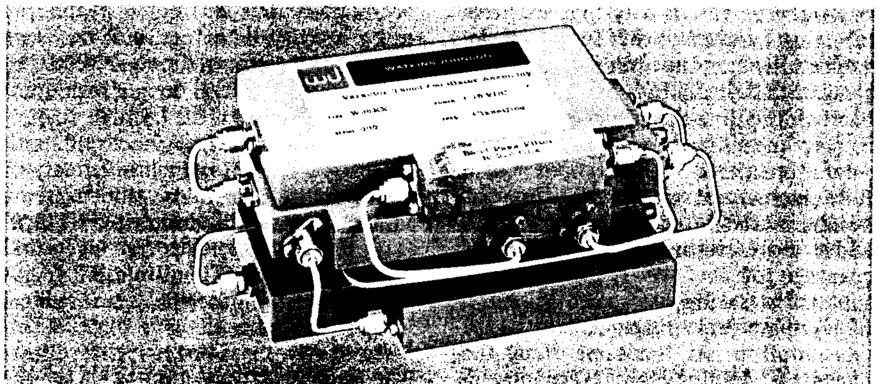


Figure 3. The total volume for a W-J miniaturized receiver is projected to be less than 100 cubic inches, with a total power consumption of less than 20 watts. The front end is configured to cover the microwave spectrum from 0.5 to 18.0 GHz. The output IF is centered at 1.0 GHz and represents 500 MHz of instantaneous bandwidth

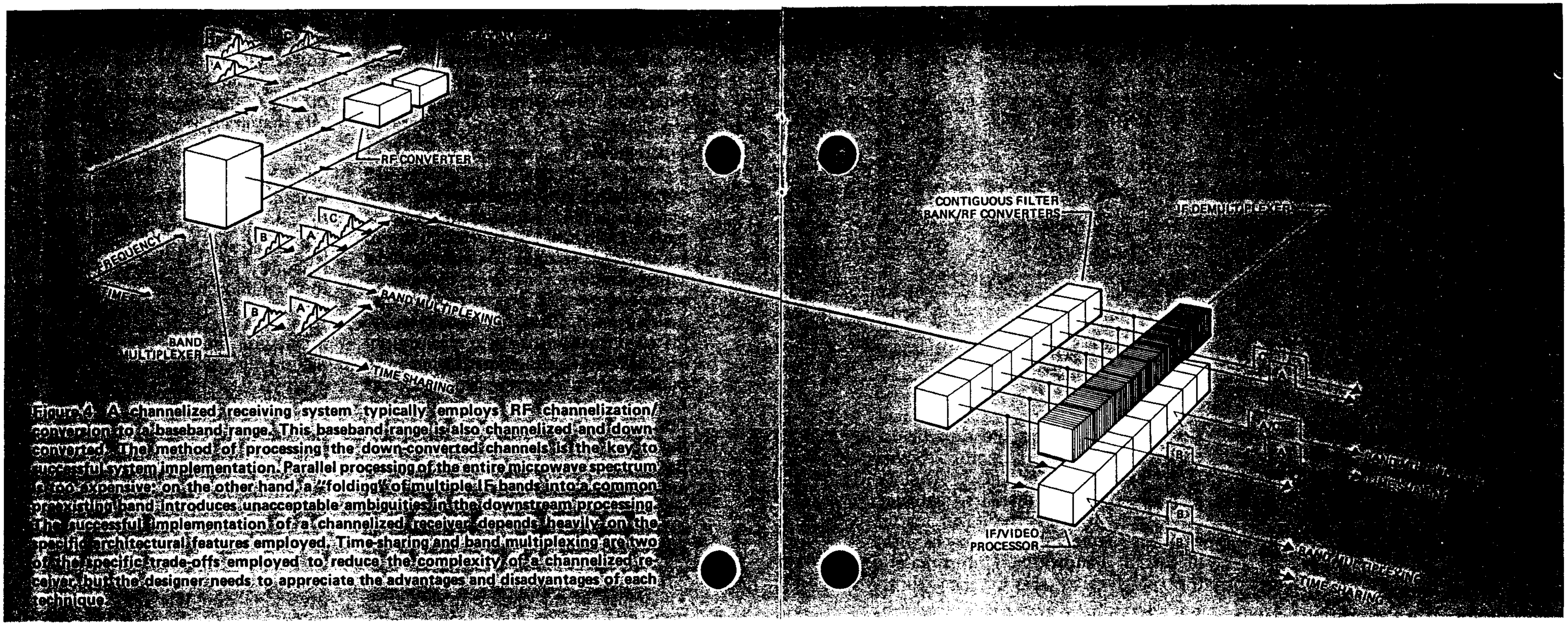


Figure 4. A channelized receiving system typically employs RF channelization/conversion to a baseband range. This baseband range is also channelized and down-converted. The method of processing the down-converted channels is the key to successful system implementation. Parallel processing of the entire microwave spectrum is too expensive; on the other hand, a "folding" of multiple IF bands into a common preexisting band introduces unacceptable ambiguities in the downstream processing. The successful implementation of a channelized receiver depends heavily on the specific architectural features employed. Time-sharing and band multiplexing are two of the specific trade-offs employed to reduce the complexity of a channelized receiver, but the designer needs to appreciate the advantages and disadvantages of each technique.

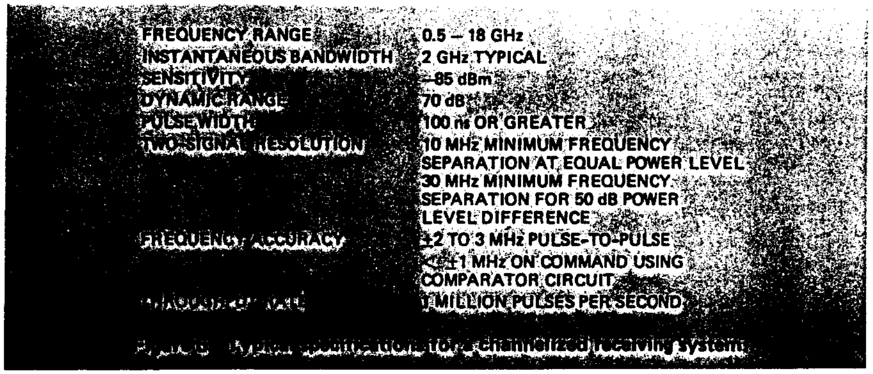
Successful implementation of a channelized receiver in modern systems applications depends on two important criteria. The first is a system architecture that avoids a "brute force" implementation, i.e., by trade-offs in the area of RF instantaneous acceptance bandwidth; time-sharing of RF/IF processing modules, etc., must be considered to avoid the complexity of a full channelized receiver. If the POI can be stated in such a manner as to allow a processor to time-share the coverage of the RF spectrum, then substantial savings accrue in the form of equipment size, weight, and power consumption. At the same time, the dangers of folding many RF bands into a single, narrowband processing channel need to be avoided, particularly in dense RF signal environments. A solution to this problem is the use of very fast activity detectors that alert the downstream processing to the presence of a signal. It is possible with today's technology to accomplish this switching technique using activity detectors on a real-time basis, i.e., response time of 30 to 40 ns or less allow the downstream processor to be switched in time to process the same monopulse event with minimum loss of signal information. This approach avoids the extreme loss of sensitivity and multiple ambiguities associated with a deep-fold approach in which multiple RF bands are summed into the same signal processing path.

The second criterion critical to the successful implementation of a channelized receiver is the application of the MIC construction techniques for the RF processing modules, SAW (surface acoustic wave) filter techniques for the IF processing modules, and LSI (large scale integration) implementation of the downstream video/digital signal processing. Channelized receivers are still very much in the "developmental" stage in this area. This is particularly true of the SAW filter technology. While it has been shown on a feasibility basis that a contiguous SAW filter bank can be designed to meet the performance criteria needed in terms of filter bandpass shapes and roll-off, it has yet to be shown that manufacturing methods and techniques exist to produce such filters on a production line basis. Thus, the systems designer is still restricted to design with discrete filters. Figure 5 shows the typical W-J specifications for a channelized receiving system.

Hybrids

While it is clear that a fully channelized receiver is not necessarily the answer to system-level requirements, it is also clear that a channelized front-end architecture suits many system-level applications. The concept of using, for example, a 2-4 GHz baseband or first-IF for the 0.5-18 GHz RF frequency range is logical from many standpoints. The most important of these is that it allows a common processing approach for a coverage in the microwave spectrum irrespective of RF frequency. Secondly, it allows attention to be focused on "common processing modules," which can be standardized for different systems-level applications.

The rapid advances in GaAs Fet technology have been brought to bear on the development of amplifiers in the 2-4 GHz range that exhibit low noise figure and high intercept points. Because of the rapid advances in solid-



FREQUENCY RANGE	0.5 – 18 GHz
INSTANTANEOUS BANDWIDTH	2 GHz TYPICAL
SENSITIVITY	–85 dBm
DYNAMIC RANGE	70 dB
PULSE WIDTH	100 ns OR GREATER
TWO-SIGNAL RESOLUTION	10 MHz MINIMUM FREQUENCY SEPARATION AT EQUAL POWER LEVEL 30 MHz MINIMUM FREQUENCY SEPARATION FOR 50 dB POWER LEVEL DIFFERENCE
FREQUENCY ACCURACY	±2 TO 3 MHz PULSE-TO-PULSE ≤±1 MHz ON COMMAND USING COMPARATOR CIRCUIT
THROUGHPUT RATE	1 MILLION PULSES PER SECOND

[illegible] Typical specifications for a channelized receiving system.

state design, specifically in development of mixers, the 2-4 GHz baseband, for example, can represent the true instantaneous bandwidth of the system. The options for viewing the spectrum through a baseband are varied: (1) a band-folding technique can be used to view the active RF spectrum simultaneously, or (2) a switching or time-sharing approach can be used.

The options for processing of signal information at the baseband level are equally varied, and result in what is herein described as a "hybrid" approach. The first of these options would employ an IFM technique to cue a superheterdyne tuner to a frequency of interest instead of utilizing the IFM as a stand-alone receiver. The second of these approaches would employ a Bragg cell (or acousto-optic) processor to instantaneously view the baseband spectrum. Finally, the third hybrid approach employs a bank of wideband superheterodyne tuners each viewing the front-end spectrum through a power-dividing RF switch matrix.

IFM Steers Superheterodyne

The typical shortcoming of a superheterodyne receiver in an EW environment is that its usefulness is limited when it encounters monopulse signals and frequency-agile signals. It is desirable, especially in jamming systems, to determine as rapidly as possible whether a newly-detected signal is one that should be jammed, kept under surveillance, or ignored.

Instantaneous frequency measurement (IFM) receivers have those particular attributes that the superheterodyne receiver lacks, such as unity probability of intercept. It can measure frequency on a pulse-by-pulse basis no matter what the frequency agility may be within its RF bandwidth. Unfortunately, the IFM receiver also has some shortcomings when used alone. Its sensitivity and frequency accuracy are not as good as a superheterodyne's, its dynamic range is limited, and it is not effective under simultaneous signal conditions.

In addition to the probability-of-intercept problem, there exists a system analysis problem that is especially evident in dense environments. Typical deployment of a superheterodyne receiver involves a scanning mode to detect a signal and a momentary hold mode for analysis. In a dense environment, a superheterodyne receiver will spend excessive time analyzing signals of little or no concern. Even if certain known frequency slots are locked out, the superheterodyne receiver will still have to continuously scan the other frequencies for new signals. Also, by locking out certain frequencies, if the signal parameters at those frequencies were to change, the superheterodyne would not detect that change.

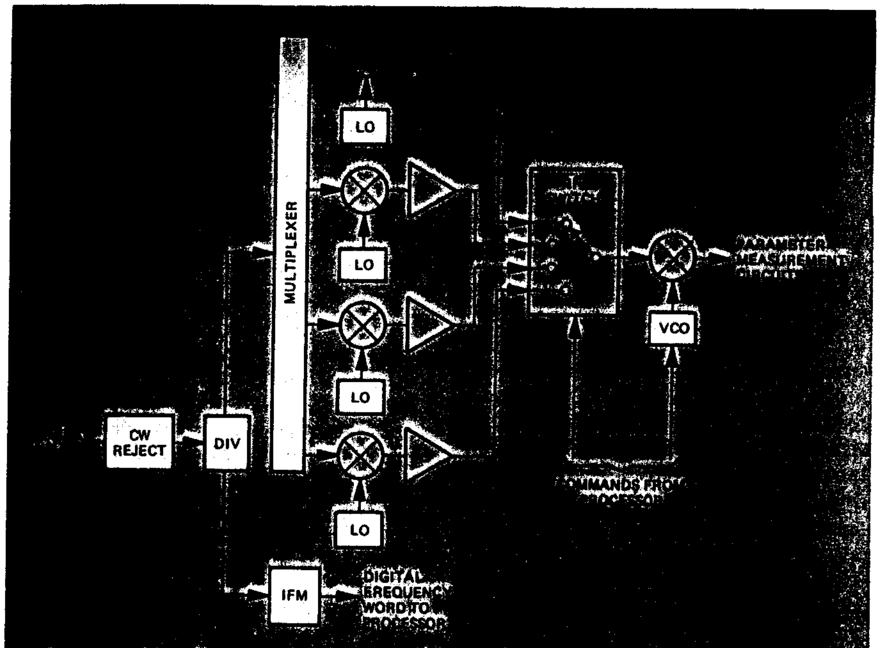
A solution to this problem is to use an IFM receiver to steer or control a superheterodyne receiver to obtain optimum signal detection and analysis (see Figure 6). A digitized IFM, one that gives frequency readouts directly in digital format, is ideally suited for this purpose. Monopulse frequency information can be fed straight to a processor in which the nonhostile or known signals are programmed. As long as these signal parameters fall within certain bounds, the superheterodyne receiver remains in a standby mode. However, if any of the signal parameters change, or if an unknown signal appears, the IFM can instantaneously command the superheterodyne to tune to the desired frequency for analysis purposes.

One possible system implementation of an IFM-steered superheterodyne uses a baseband-coverage IFM to steer a channelized scanning superheterodyne (see Figure 7). A power divider routes half of the signal to the channelized front end and the other half to the IFM receiver. The output of the IFM is a digital word indicating the frequency of the signal within ±10 MHz. The preprogrammed processor then determines whether or not this signal is one that should be analyzed. If this frequency were already cataloged as a nonhostile signal, then it would be ignored and the channelized scanning superheterodyne receiver would remain at whatever task it was previously performing. If, however, the signal is of unknown origin, the controller commands the IF switch to select the channel in which the signal is present. Simultaneously, the fast-tuning VCO will be commanded to scan the ±10-MHz band around the indicated frequency. The scanning receiver will then proceed to analyze the signal as required.

The advantage of this technique is that the scanning receiver will spend time only on signals of potential interest. If more detailed preprocessing is desired, other signal characteristics, such as pulse width and PRF can be derived from the IFM for signal identification. Once it is decided that the signal should be investigated, the scanning receiver can be directed to within ±10 MHz of the signal.

By channelizing the 2.6-5.2 GHz range (for example) and down-converting to approximately 650-1300 MHz, a very rapid tuning and stable VCO can be used. The 2.6-5.2 range is considered a "baseband" frequency range for ECM systems. Frequency coverage outside of this baseband range is handled by broadband RF converter modules, which supply a first IF of 2.6-5.2 GHz to the receiver. Similarly, for reconnaissance application, the baseband frequency range is 2-4 GHz and the rest of the frequency spectrum is converted into this baseband region in 2-GHz "chunks" by means of wide-

Figure 6. This prototype analog version of a Watkins-Johnson hybrid IFM/superheterodyne receiver covers the 2-to-4 GHz baseband frequency range. The radial strobe on the polar IFM display represents a test signal down-converted from the 94-GHz range. A direct RF to digital form of this receiver has been prototyped for [illegible]



[illegible] The IFM-steered superhet overcomes many of the disadvantages of either [illegible] used as a stand-alone system. The IFM enhances system probability of intercept while the superhet is set-on to specific frequencies for signal analysis purposes.

band RF converter modules, as discussed previously.

One problem present in any IFM system is the occurrence of simultaneous signals. For two signals of nearly equal power, the IFM will typically indicate a frequency somewhere between the two actual signals. This problem is taken care of by a simultaneous signal detector, located within the IFM receiver, which not only indicates the presence of simultaneous signals but also inhibits the output of the IFM so that no false frequency readouts are processed. If the two signals have a greater than 4-dB power difference, then the IFM will give a correct reading of the higher power signal. The threshold of the simultaneous signal detector can be set to allow the signal to be either processed or inhibited, as desired.

The other problem of an IFM system is the presence of a CW signal, which would, in essence, cause any other signal to be considered a simultaneous signal. An automatic tunable CW reject filter is used to detect and automatically notch-out any undesirable signal. This same reject filter can be used to assist the system in identifying simultaneous signals. When the simultaneous signal detector indicates the presence of simultaneous signals, the reject filter can be commanded to sweep the frequency range of interest. At the instant the filter rejects one of the signals, the indicator will turn off and the IFM will give a true reading of the unrejected signal. At the same time, knowledge of the frequency of the tunable reject filter will indicate the frequency of the other signal.

The reject filter is also valuable in jamming systems where lookthrough is desired. By notching out the jamming signal, the receiver can still be used during jamming. This assumes that enough isolation is present between the transmit and receive antennas.

Bragg Cell

The Bragg cell receiving system usually consists of a channelized form of front-end processing combined with a Bragg cell IF processor (see Figure 8). This permits use of Bragg cell technology at an intermediate frequency (IF) for which the Bragg cell is compatible. Current technology generally allows such processing to occur at frequencies through L-band, although some developmental work is occurring in the S-band range. Nevertheless, the Bragg cell approach allows a contiguous array of filter detectors to be formed instantaneously across an IF passband that may extend from a few hundred MHz to as wide as 1 GHz. As technology permits, this capability is expected to be extended still further. As an example, within 1-2 years, it may be possible to array a thousand photodetector cells across the 2-4 GHz baseband range to achieve 2 GHz of instantaneous RF acceptance bandwidth, with 2 MHz frequency resolution. The current state-of-the-art bounds, both in terms of instantaneous bandwidth and dynamic range, are primarily due to physical limitations within the optical photodetecting arrays (see Figure 9). The optical principles employed will not be reviewed here except to summarize the operation of the device.

A wideband IF causes an acoustic wave to propagate in a crystalline substrate. A coherent (laser) light source is diffracted by the substrate, producing a spatial distribution, by frequency, of the incident IF energy. A photodiode array then detects the diffracted light beam and translates the output to provide frequency information. The effect is similar to utilizing many contiguous narrowband IF strips to analyze the signal. Sensitivity to CW is high for this receiver, while pulse sensitivity varies with pulse width. POI within the passband can approach unity, but the FAR depends upon the sorting criteria.

The principal value of the Bragg cell processor is that it allows a wide portion of the RF/IF environment to be viewed instantaneously, while achieving fine frequency resolution at the output. A general rule of thumb is that a compression factor or equivalent time bandwidth product on the order of 10^3 is achievable, i.e., for an instantaneous bandwidth of 1000 Mhz, a 1 MHz frequency resolution at the output should be realizable. Figure 10 gives typical system specifications for a Bragg cell-based receiving system. The processor is very similar to a channelized receiver in that multiple simultaneous signal events can be viewed without introducing unwanted intermodulation products within the specified operating dynamic range of the processor. This capability is, of course, limited by the physical laws governing the proximity and relative power levels

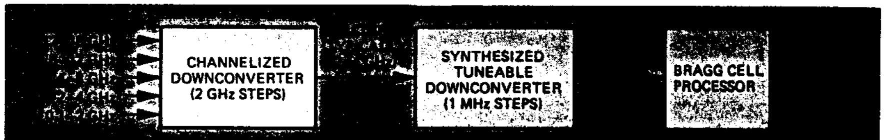


Figure 8. A channelized form of front-end [illegible] oscillators and a synthesized tunable down[illegible] to be configured in a typical systems [illegible] vironment with high probability of intercept [illegible] while at the same time yielding a system [illegible] of approximately ±1 MHz.

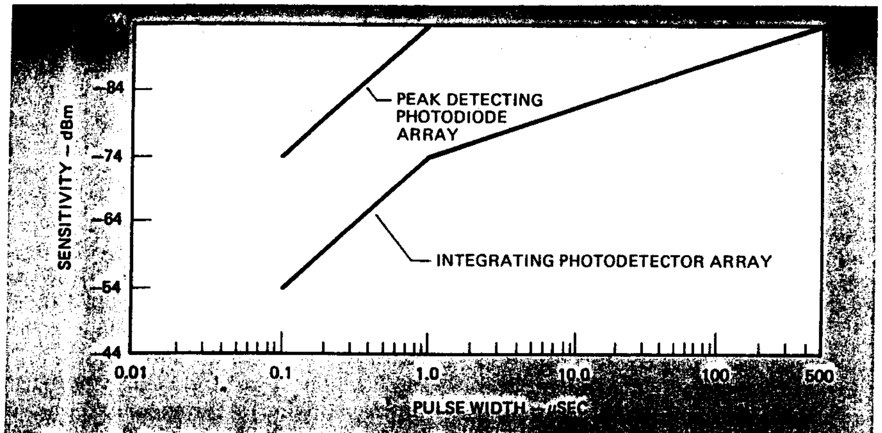
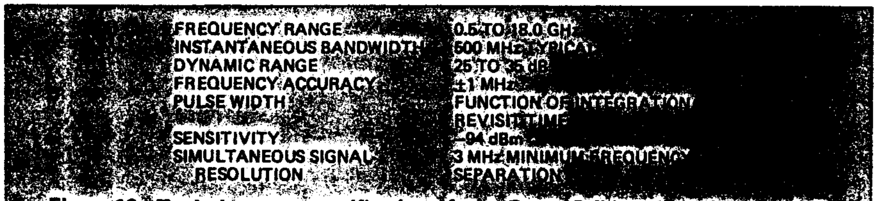


Figure 9. Sensitivity of current Bragg cell photodetector technology is limited for narrow pulse widths and/or low-duty-cycle signals. Sensitivity to pulse widths below 1 to 5 μs decreases rapidly. Current developmental efforts are aimed at overcoming this limitation through development of a peak detecting array exhibiting the electrical equivalent of a "sample and hold" circuit characteristic.

associated with multiple sin x/x spectral distributions in the frequency domain. In addition, there is still the problem of determining the centroid of the power spectral distribution, i.e., a number of photodiode cells will be illuminated by the diffracted laser beam in accordance with the power spectral distribution of the signal. If one wishes to use the Bragg cell processor as a receiver instead of a spectrum analyzer, then a centroid of the power spectrum must be determined.

There is also the problem of reading out the photo-detector array — it is normally not possible to accomplish this in a parallel format, so a sampling technique is required to read out the status of the diodes in the array. This is an obvious limitation in terms of real-time processing of signal information. At present, marketed Bragg cell receivers use energy detectors (integrating photodetector arrays) and hence, PRI and pulse-width sorting is not feasible. However, work is being done by at least one Bragg cell vendor on development of a peak detecting optical diode array that allows good sensitivity against a pulsed RF signal environment. There is work sponsored by government R&D laboratories on integrated forms of such processors, but performance does not yet match that attainable with discrete devices. By far the most severe limitation of the processor is that it is an energy device akin to a radiometer, which means that its sensitivity to narrow pulses or



FREQUENCY RANGE	0.5 TO 18.0 GHz
INSTANTANEOUS BANDWIDTH	500 MHz TYPICAL
DYNAMIC RANGE	25 TO 35 dB
FREQUENCY ACCURACY	±1 MHz
PULSE WIDTH	FUNCTION OF INTEGRATION/ REVISIT TIME
SENSITIVITY	–94 dBm
SIMULTANEOUS SIGNAL RESOLUTION	3 MHz MINIMUM FREQUENCY SEPARATION

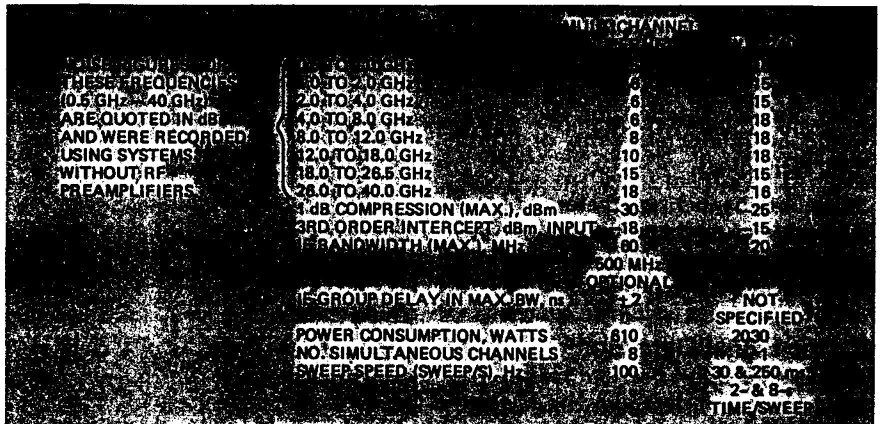
Figure 10. Typical system specifications for a Bragg Cell-based receiving system.

low-duty-cycle signals is severely limited. However, developmental work is in progress to achieve a peak detecting photodiode array that will overcome this limitation to a significant degree. Other developmental work is concentrating on multichannel versions of such processors to accomplish direction finding as well as determining the carrier frequency of a signal.

The Bragg cell processor allows the equivalent of a very large number of resolution cells to be implemented with a single device. The channelized front-end architecture allows the instantaneous bandwidth of the Bragg cell processor to be time-shared, as discussed previously, to cover the entire RF spectrum of interest.

Multichannel Superheterodyne System

The multichannel superheterodyne receiving system approach offers increased flexibility over a simple superheterodyne receiver and substantially increases the probability of signal intercept (see Figure 11). The basic technique employed in a multichannel concept is to first convert all input bands into a common baseband range, i.e., use a channelized form of front-end RF processing, as described earlier. The specific baseband range to be chosen has often been the 2-4 GHz range for reconnaissance receiving applications, or 2.6-5.2 GHz for ECM systems applications. A specific IF of 4-8 GHz has often been chosen for covering the millimeter wave range. A choice of 2-8 GHz would include the capability to service the entire electromagnetic RF spectrum of interest. A multiple number of receivers or tuners are then employed at the baseband RF frequency range and are connected to the converted RF input bands through an RF switch matrix that permits multiple baseband receivers to be connected to a given RF input band, thereby improving the system's flexibility. All baseband receivers are identical and can exhibit the bandwidth characteristics discussed earlier, i.e., several hundred MHz. This configuration also enhances system probability of intercept. Each of these baseband receivers can then be configured as an integrated subassembly using advances in GaAs Fet technology to minimize system weight and cost. Watkins-Johnson has, for example, projected a size of less than 100 cubic inches (using today's technology) for a 0.5-8 GHz baseband tuner module with built-in synthesizer. Since each of these miniaturized baseband receivers can provide a wideband IF output, further processing can take advantage of Bragg



		MULTICHANNEL	[illegible]
[illegible] THESE FREQUENCIES (0.5 GHz – 40 GHz) ARE QUOTED IN dB AND WERE RECORDED USING SYSTEMS WITHOUT RF PREAMPLIFIERS	[illegible] TO 2.0 GHz	6	15
	2.0 TO 4.0 GHz	6	15
	4.0 TO 8.0 GHz	6	18
	8.0 TO 12.0 GHz	8	18
	12.0 TO 18.0 GHz	10	18
	18.0 TO 26.5 GHz	15	15
	26.0 TO 40.0 GHz	18	16
	1 dB COMPRESSION (MAX.), dBm	30	25
	3RD ORDER INTERCEPT, dBm INPUT	18	15
	IF BANDWIDTH (MAX.), MHz	60 500 MHz OPTIONAL	20
	IF GROUP DELAY IN MAX. BW, ns	±2	NOT SPECIFIED
	POWER CONSUMPTION, WATTS	610	2030
	NO. SIMULTANEOUS CHANNELS	8	[illegible]
	SWEEP SPEED (SWEEP/S), Hz	100	30 & 250 ms 2- & 8-s TIME/SWEEP

Figure 11. Multichannel Superheterodyne vs. typical system.

cell processors, frequency discrimination for IFM's or channelizing contiguous filter banks. Thus, the types of IF processing used are dictated by specific system requirements. Furthermore, the control architecture can be made compatible with addition of such an "RF front-end design" directly into existing receiving systems. The system design also permits frequency expansion into the millimeter wave portion of the spectrum by means of additional converter modules. The exact choice of the RF switch matrix configuration is a system design trade-off dependent upon the signal densities expected in the environment.

Alternatives for the subsequent wideband IF processing in the multichannel configuration are many and varied. Bragg cells are one alternative; a second is frequency discriminator IFM's. In the latter case, the discriminator function is formed over an IF passband of several hundred MHz (instead of the several thousand MHz in conventional IFM receivers), thus limiting the false alarm rate due to multiple simultaneous signals in the IFM passband. The output from this discriminator circuit could then be used to set-on the narrowband IF processing channel for detailed signal analysis. A third alternative for wideband IF processing would be the channelized filter-bank approach. A multiplexed IF output down-converted to a lower IF range would feed a channel-bank of filters to yield unambiguous frequency resolution on a pulse-to-pulse basis of 5-10 MHz. Implementation of the filters would be in discrete form or utilize SAW technology.

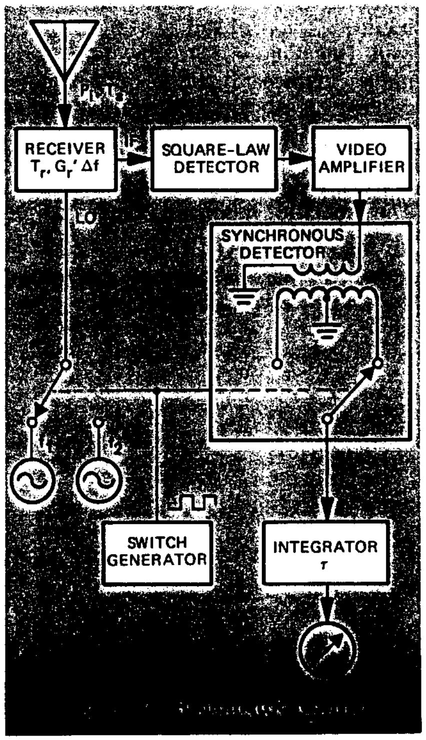
The multichannel superheterodyne receiver yields perhaps the best overall systems configuration from the standpoint of satisfying a large number of requirements.

Exotic Signal Detection and Processing

Besides those discussed in this article, other forms of receivers are also being studied for special applications.

Radiometric Receivers. The radiometric technique (see Figure 12) offers better sensitivity for detecting low power signals in the millimeter wave portion of the radio spectrum. A theoretical improvement of up to 30 dB is possible over conventional superheterodyne receivers (-140 dBm in a 1 MHz bandwidth). By switching the L.O. frequency instead of the front-end (as in a Dicke-switched configuration) receiver gain fluctuations can be cancelled by calibrating the receiver against its equivalent noise temperature at an adjacent frequency where no signals are present.

Multiplicative Receivers. The multiplicative approach (see Figure 13) is used to detect the presence of spread spectrum signals with suppressed carriers. For example, if one were searching for a biphase coded signal hidden in a noisy RF environment, a search for the carrier at twice the signal frequency would be made. An RF phaselocked loop can be used to demodulate the passband IF of the receiver to yield the actual biphase code output. The approach is straightforward for CW spread spectrum signals, but pulsed signals present a problem because of the finite time required to achieve phase-lock on the signal. Studies are currently under way to address the development of an AFC loop that can be tuned in a time period that is short compared with the pulse duration.



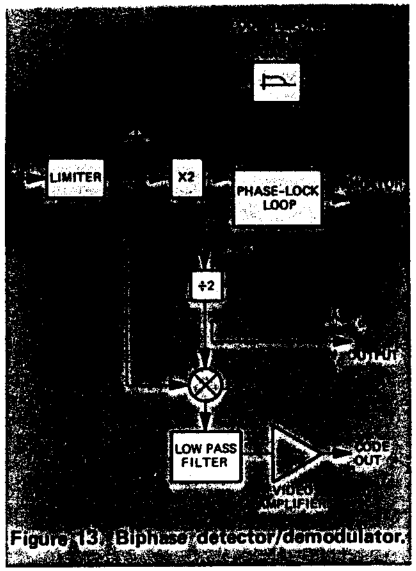


Figure 13. Biphase detector/demodulator.

Feature Extraction. This term ordinarily applies to the extraction of the phase keying rate (chip rate) of digitally phase-modulated signals. Applications for this receiver technique include wideband signal detection, analysis, and waveform identification. All of this can be accomplished with signal-to-noise ratios of less than unity. The detection process involves driving a detector with an extremely accurate low-frequency synthesizer to yield a frequency translated chip rate line that is within the low-frequency range of a high-resolution spectrum analyzer. The narrow bandwidth of the spectrum analyzer filters provides the processing gain required to detect and measure the chip rate in the noise.

* * *

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Mr. Harper is currently Head of the Advanced Applications Engineering Section in the Recon Division. In this capacity, he supervises several account activities and maintains personal account responsibility for all R&D programs within the Division. In the latter capacity he assists in directing the IR&D activities of the Recon Division. He has been heavily involved in the channelized receiver area of technology and has written numerous technical articles for various trade journals. His experience includes a strong antenna background.

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