is disabled during this flyback operation, so that no signal will appear above the detector's minimum signal level. The forward and backward sweeping motion of the frequency of the LO will continue for as long as there is a detectable signal from the victim radar. In other words, the sweeping LO is banged downward in frequency every time a signal is detected, and then allowed to sweep upward again as it does in the normal search mode. This accounts for the name. Note that the frequency-time slope is the same in Figure 151 (b) regardless of whether the spot jammer is in search or lock. In an actual system the sweep rate may be adjusted to be considerably higher in the lock mode, so that multiple dwells on the victim bandwidth would occur on every victim radar PRI. The sweep rate in the lock mode may even be adjusted to dwell in the victim radar's passband for one pulse width, thereby matching the jammer to the radar's bandwidth. For ECM transmission, the signal frequency of the sweeping local oscillator is mixed with a local oscillator at the frequency of the IF amplifier, and the incorrect sideband filtered out. This sawtooth deviated FM signal is then further modulated by a noise source before being amplified by the power amplifier. The ECM signal is then radiated by the antenna.

Barrage Noise

Definitions, Advantages, and Disadvantages

This is a self-screening or support ECM technique that radiates noiselike energy over a wide-band for the purpose of masking expected received signals of a victim electronic system.

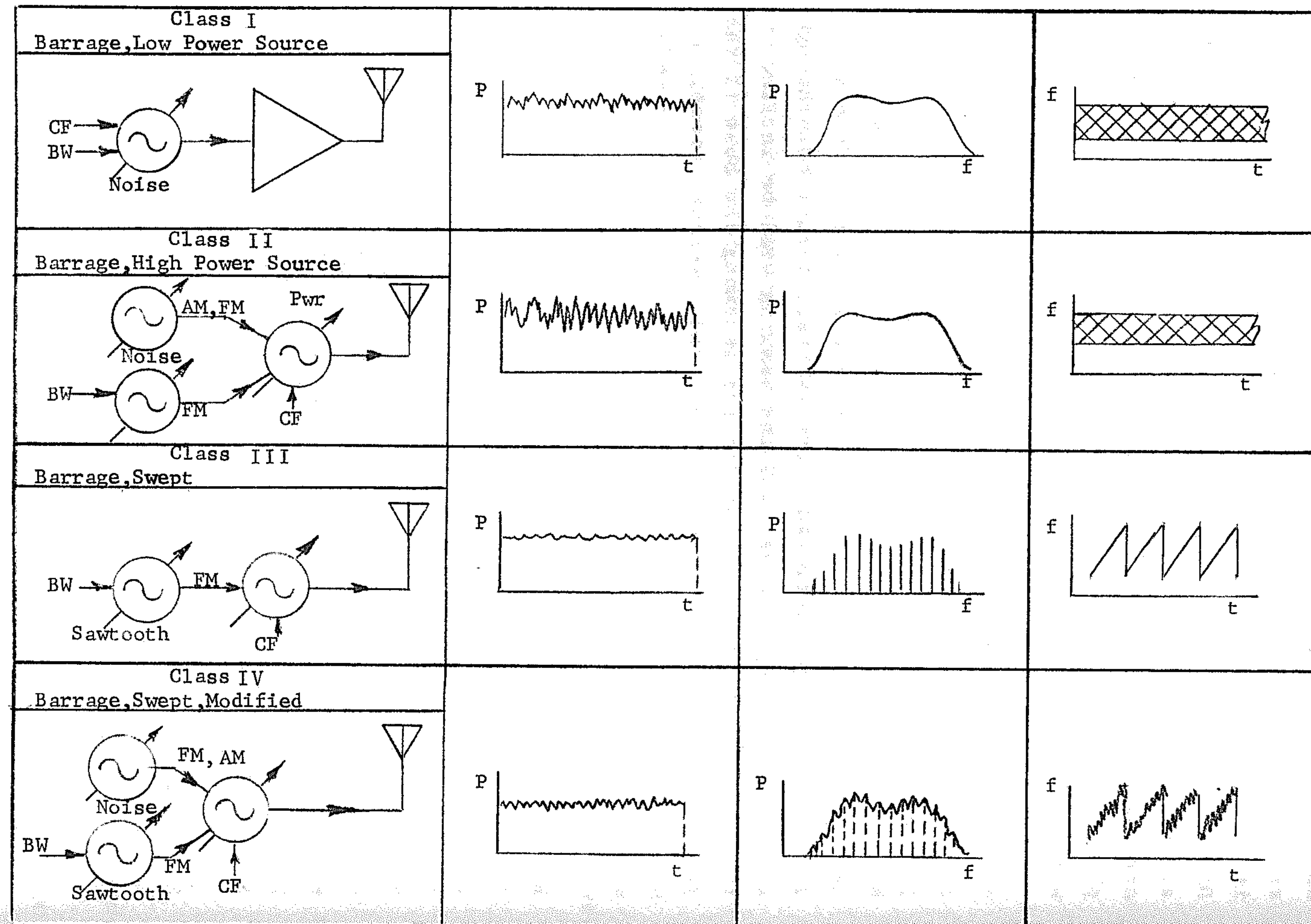
Barrage noise signifies the spreading of noiselike jamming energy over a wide frequency band such that many victim radars can be jammed over their whole agile bandwidths simultaneously. Bandwidth on the order of 100 Mhz to an octave is thought of as being barrage. The barrage jammer can produce wide-

band noiselike jamming power in many ways. For instance, resistor noise can be amplified directly up to a level where it can be radiated from an antenna. This is called DINA, Direct Noise Amplification. Various forms of AM, PM, and FM are also used on either low-level power sources, like semiconductor RF oscillators that can be frequency, amplitude or phase controlled, or high-level power tubes like the backward wave oscillator (BWO), or the traveling wave tube (TWT).

The disadvantage of barrage noise is that the jamming power is diluted by being spread over a wide frequency band. The jamming effectiveness is dependent on the jamming density in W/Mhz. Widening the jammer's bandwidth lowers the power density when the jammer power available is fixed. With a sufficiently high-power radar transmitter, target burnthrough may occur at large ranges, and the jamming will be ineffective. However, this form of jamming is among the best if the jammer designer can achieve the required power densities, because it is not intelligence-sensitive like many forms of smart noise and deception-jamming schemes.

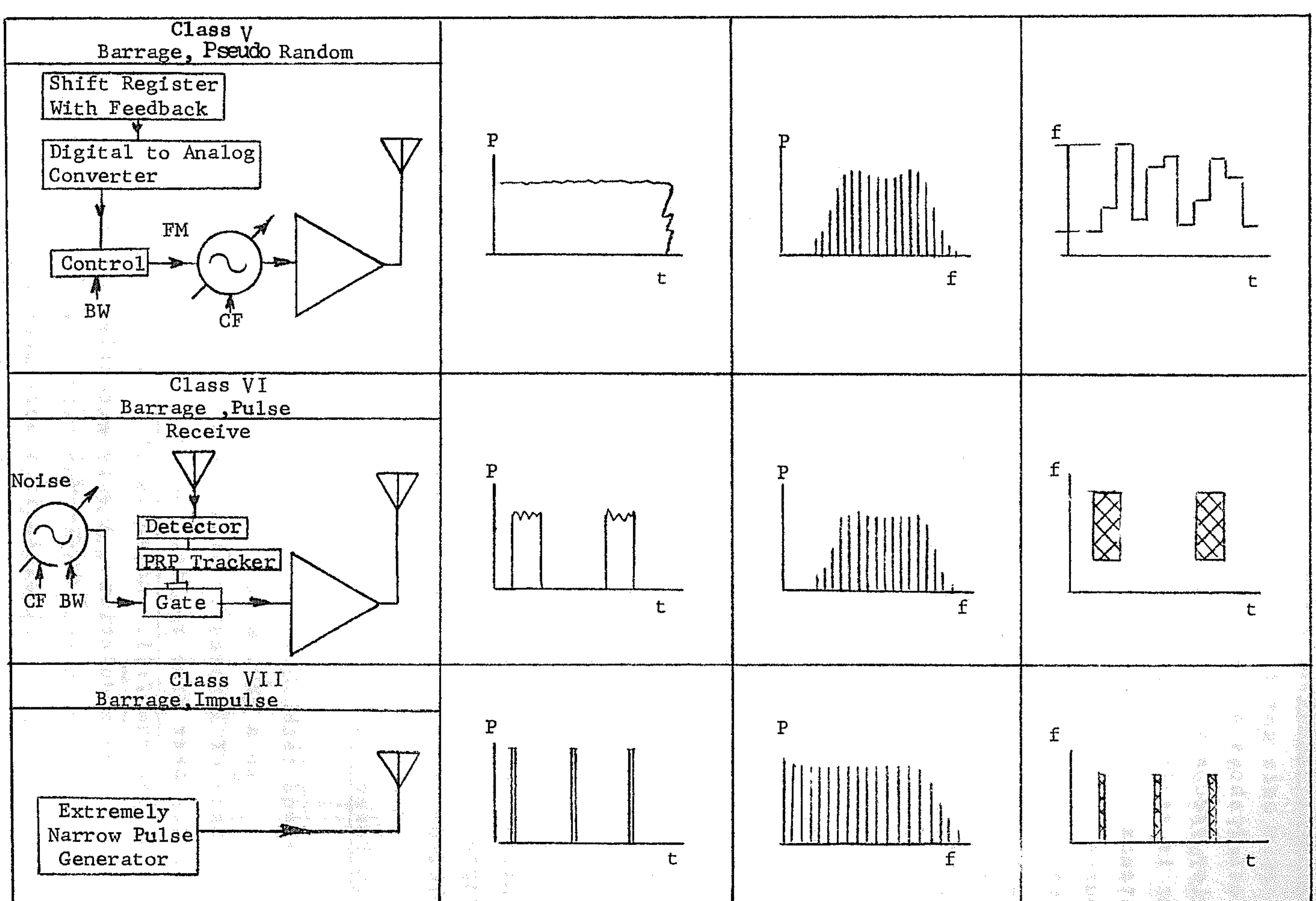
Barrage noise can be used equally well for self-screening, stand-off, support or off-board applications. Since it is the oldest type of jamming, the opposing sides in a conflict will have considered the barrage noise problem and will have devised ECCM against it. For instance, the tactical missile will almost always have a HOME-ON-JAM (HOJ) mode, which will produce angular guidance signals to its autopilot comparable to those produced from the normal unjammed skin return signal from the target.

Seven generic classes of barrage noise jamming are shown in Figures 152 and 153. Many combinations of these are also possible.



BW=Bandwidth,CF=Center Frequency.

BARRAGE NOISE CLASSES ,FIGURE 152



BW=Bandwidth,CF=Center Frequency

BARRAGE NOISE CLASSES, FIGURE 153

Low Power Source

Class I shows a low-level noise source, which could be a noisy vacuum tube or a semiconductor noise diode, whose output is amplified to a suitable level for radiation by the antenna. A simple resistor could be used for the noise source to produce DINA; however, the amount of gain required usually makes such a design impractical. The frequency of this type of jammer is controlled by selecting the correct noise source, by heterodyning techniques or by filtering. The bandwidth is controlled by noise source selection and by filtering if needed.

If an attempt is made to amplify a white-noise or pseudo-white-noise signal up to a level suitable for jamming, certain precautions must be taken. Although white-noise has a spectrum which is continuous and uniform over the band of interest, it also has spikes that extend 10 db and higher above the average level of noise. When this is amplified by a TWT, the noise spikes saturate the TWT beam, suppressing the smaller level constituents of the noise signal. Clipping of the noise prior to amplification is usually required to minimize this effect. See The Application of TWTs to ECM in Chapter 3 and CLIPPED NOISE JAMMING in Chapter 4 for further related information.

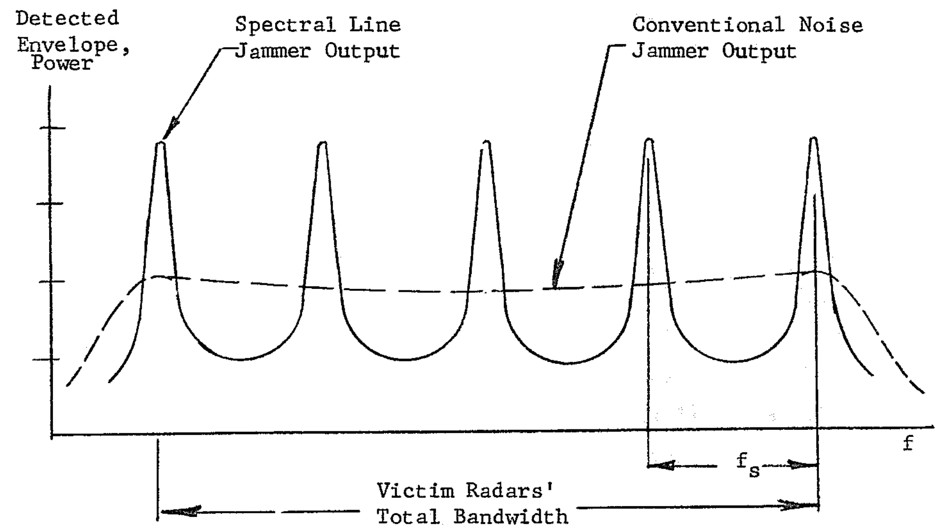
High Power Source

The second technique, Class II, shows a high-power noise source, like a BWO, which is capable of being tuned over the whole band of interest. Sine waves are used to deviate the frequency over wide ranges. Noise is added to the sine wave to get spectrum fill. Noise is also used at the same time for amplitude modulation. A very effective jamming spectrum can be produced in this way. The rate at which the frequency is modulated by the sinusoid is a very important factor in designing an effective jammer. Sine-wave modulation frequencies well in excess of 100 times the victim radar PRF are

desirable. The bandwidth of this class of barrage-jammer is fundamentally controlled by the amplitude of the sine wave and noise signal that produce frequency deviation. The center frequency of the barrage is controlled by varying the average d-c voltage applied to the BWO.

Swept

Class III consists of a high-power voltage-controlled oscillator (like a carcinitron or BWO) being frequency modulated by a fast sawtooth voltage waveform. This is also called comb jamming. The proper amplitude of the sawtooth signal, when applied to the modulation terminal of the oscillator, causes the frequency of the output transmitted power to sweep over the whole barrage bandwidth of interest. The speed of the sweep determines the spacings between the spectral lines in the power output versus frequency graph. For example, a ten Mhz sweep speed will cause spectral lines to appear every ten Mhz over the barrage bandwidth. The shape of the resulting spectrum is nearly a chimney when the sawtooth



SPECTRAL LINE JAMMING COMPARISON WITH CONVENTION NOISE JAMMING
FIGURE 154

modulation is performed with reasonable purity. The center frequency is controlled by varying the average d-c voltage applied to the oscillator voltage-control anode. The bandwidth is controlled by varying the amplitude of the sawtooth signal. A comparison of this spectral line type jammer with conventional noise jamming (like that produced from Class I or II barrage jammers) is shown in Figure 154. It is assumed that the two jammers have the same power capability and both are operating continuously. Both jammers are shown adjusted to spread over the victim radar's total operating bandwidth. If the spectral lines of the Class III jammer are produced with a purity such that the average line widths are about (1/n)th of the sweep speed f_s, then the Class III jammer power peaks will be greater than the conventional noise jammer level by almost (10 log n) db. The time or period of the sawtooth should be equal to or less than the reciprocal of the radar bandwidth so that adjacent jamming spectral lines do not suppress each other. Best jamming of a chirp radar is achieved by setting the sawtooth period equal to the wide pulse-width so that there will always be a signal in the radar's compression filter.

Swept, Modified

The Class IV barrage jammer utilizes a sawtooth frequency modulation plus an additional noise FM and an additional noise AM, applied to either a low-power or high-power oscillator. A spot FM band of noise sweeps across the barrage band, and the composite output signal is amplitude-noise modulated. A good jamming signal can be produced with this concept that looks very close to a white-noise signal (a continuous and uniform frequency spectrum) over the barrage bandwidth. The average value of the d-c voltage applied to

the frequency control of the oscillator controls the center frequency of the barrage, and the amplitude of the frequency-deviation signal controls the bandwidth.

This class also covers contiguous subcarrier barrage noise. Here the intent is not to produce a spectrum approaching white noise. Instead, distinct subcarrier spacings are required that are related to the wide and narrow bandwidths of a WIDE-BAND LIMITING radar receiver. See Chapter 5 for further details.

Pseudorandom

The Class V barrage jammer uses a regenerative shift register to generate a pseudorandom sequence. This is sometimes called digital noise. The digital noise is converted to analog and used to control the frequency of an oscillator, thereby making the frequency of the jammer a precise function of the digital state of the shift register. This provides the ECM set designer with a convenient way to control the instantaneous frequency of the oscillator but still provide a complete barrage coverage. See the Pseudorandom Sequencing section in Chapter 3 for more information.

When compared to the Class I or Class II barrage noise, digital noise has about the same effectiveness at the victim radar receiver's video level due to its video nature. If the pseudo random sequence length is synchronized with the victim radar's PRF, a synchronized, multiple, false-target situation is developed on the PPI scope that can be more deceptive than plain noise strobing. When digital noise is used to jam many different frequency radars, the clock frequency should be about equal to the reciprocal of the widest PW employed by the victim radars. Other advantages of digital noise are: one, it can (by suitable modification of the pseudorandom sequence) produce a noise floor over a given frequency band while simultaneously jamming one or more specific radar frequencies, and two, it can generate jamming waveforms like those described under MULTIPLE SWEPT-NOISE JAMMERS, CONTROLLED.

Pulse

The Class VI barrage jammer covers the whole barrage band in frequency but is not on all the time. This technique is also called noise cover pulse. It covers the repeated skin return from the target with a gated barrage signal which brackets every repeated pulse. This can be a very effective technique against the range-tracking radar because the barrage signal is always within the range gate of the victim radar. In certain cases this type of jammer will act as a beacon to a radar. See COVER PULSE JAMMING for further detail.

REPETITIVE NOISE, as described later in this chapter, is a form of this class of barrage jammer where the noise within succeeding pulses is repeated for fixed amounts of times, and where the pulses are just touching, to produce a CW signal.

Impulse

The Class VII barrage jammer is the impulse type. It is well known that a very narrow pulse or impulse will produce a spectrum containing a wide-band of frequencies starting at very low values and extending into the RF band. The narrower the pulse the further out the spectrum will stretch. Since there is very little average power in the impulse waveform, the amplitude must be high enough to make up for this. The impulse barrage jammer will tend to cause transient effects in victim radars. Another use of this type of barrage signal is that it can provide an RF memory signal into the radar

bandwidth which could be gated ON and OFF for RANGE-GATE WALKOFF action. The amplifier and the device that produces this type of ECM signal is special and can not be likened to any of the other means of barrage generation. This type of noise is countered by limiters in the radar receiver.

Other names that have been used for the above BARRAGE NOISE classes are:

Sawtooth Modulated Jamming
Sine-wave Modulated Jamming
Systematic Modulated CW
Swept-Frequency Jamming
Swept FM by Noise
Swept AM/FM
Swept Jamming
Swept Noise
Contiguous Subcarrier Barrage

Barrage/Spot Sequence Jamming

This is a self-screening or support ECM technique that uses both spot and barrage noise to confuse an ECM PRELOOK, FREQUENCY AGILITY radar.

Some FREQUENCY AGILITY radars will search their operation frequency band for the least jamming activity frequency and then transmit at that frequency. This look-transmit-listen action can take place for every radar pulse transmitted or for blocks of pulses transmitted. Reference should be made to Chapter 5 under LOOK-TRANSMIT-LISTEN. The ECM technique described herein will decrease the effectiveness of this ECCM. A very flat jamming spectrum of the total operating band of a radar would not permit the LOOK-TRANSMIT-LISTEN ECCM to be effective, but this is a very difficult task for ECM