Electronic Countermeasure (ECM)

MARCH 29, 2016SEPTEMBER 19, 2016

Brief

Ever since radar being used in battle in an attempt to gain superior situation awareness and guide weapons, various techniques were created to reduce the effectiveness of those sensors. Whiles passive countermeasure such as Stealth (https://basicsaboutaerodynamicsandavionics.wordpress.com/2016/03/04/stealth-techniques-and-benefits/) techniques were invented to help military assets hide and stay invisible from enemy's sensors, electronic countermeasure techniques were invented to confuse, overwhelm adversary sensors so that they are unable to track or attack friendly assets.This article will introduce and explain some common countermeasure techniques used by military aircrafts.

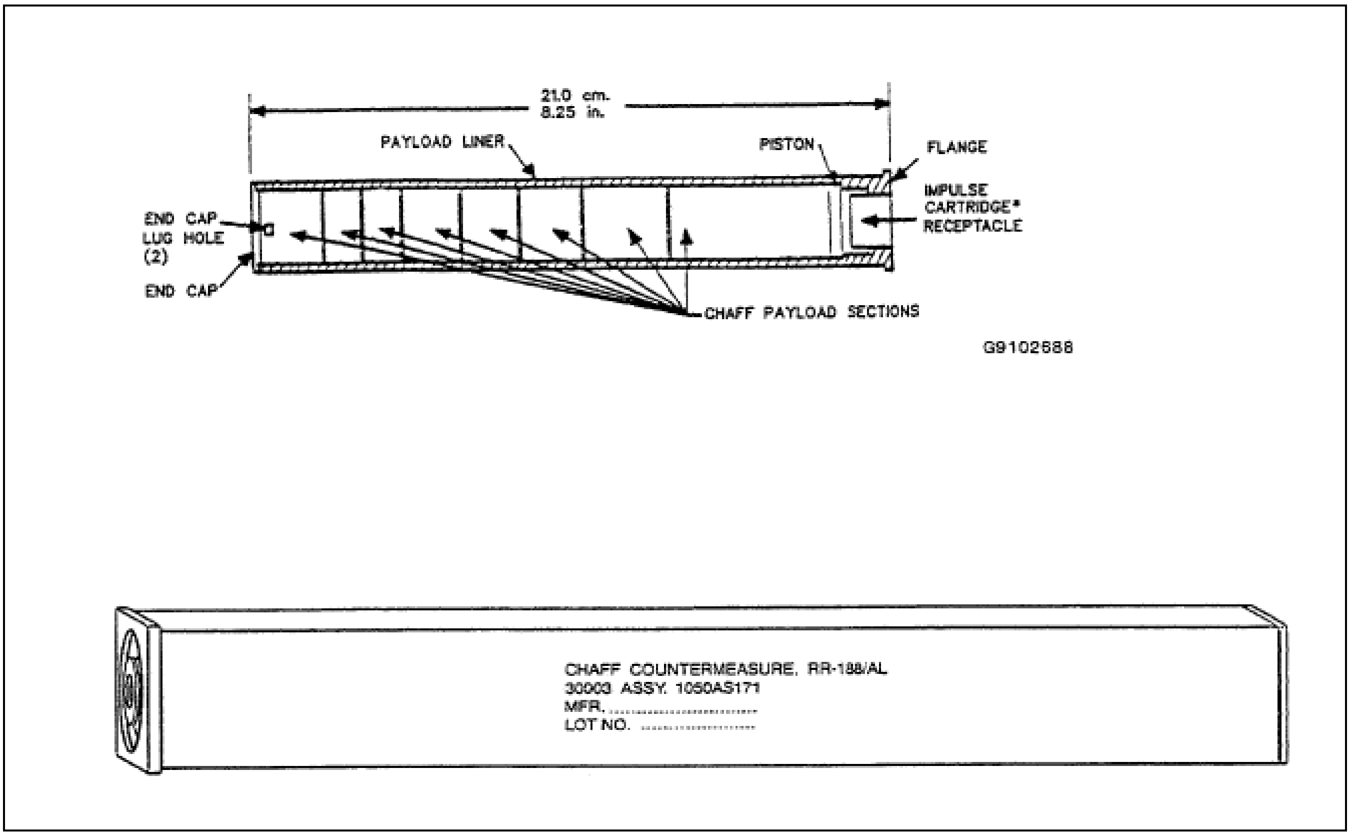
Physical Configuration

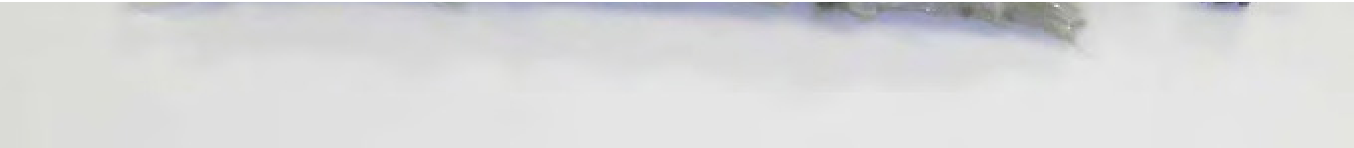
Radar countermeasure devices on aircraft take various shape and forms.Each configuration styles has their own advantages , disadvantages which will be explained below.

Chaff:

The most basics electronic countermeasure device, was invented in War world II and used by all military aircraft nowadays.Chaff consists of extremely small strands (or dipoles) of an aluminum-coated crystalline silica core. When released from an aircraft, chaff initially forms a momentary radar reflective cloud and then disperses in the air and eventually drifts to the ground. The chaff effectively reflects radar signals in various bands (depending on the length of the chaff fibers) , the effective frequency bandwidth of a single chaff length are varied by ±5% , but various chaff length are often mixed to increase chaff effective bandwidth . Immediately after deploying chaff, the aircraft is obscured from radar detection by the chaff cloud which momentarily breaks the radar lock. To maximize the effectiveness of chaff before release them pilots often perform beam maneuver (fly at the direction perpendicular to adversary radar to reduce doppler effect).The effect of chaff to radar is similar to a smoke screen to naked eyes.

Example: photo of RR-188 a single cartridge containing 400,000 chaff dipoles, each in 8 cuts, a plastic end cap, piston, and felt pad.





Advantages:

- small in size, can be carried in large number without affecting carried aircraf's weapon load
- decoys deployment doesnot affect aircraft maneuver in any way

Disadvantages:

- Chaff decelerated quickly after being released, as a result there is a great difference between speed of carrier platform and chaff thus Doppler radar reduce effectiveness of chaff significantly.

<u>ECM pods:</u>

As internal space on fighters is limited , they often carry their jamming system inside pod outside the airframe. Jamming pod confuse/suppress adversary radars by sending out radio wave at the same frequency as the radar .The main component of ECM pod are receivers , techniques generator and transmitters , powerful ECM pods sometimes have ram air turbine to generate their own electrical power instead of relying on aircraft's generator . Jammer pods are often carried on aircraft centerline station, some dedicated support jamming asset such as EA-18G may carry more than 1 jammers in which case the pod can be carried on wing stations too.

Advantages:

- Aircraft can carry more than one jamming pod , mix-match difference kind of jamming pods to satisfy missions requirements allow higher flexibility compare to internal systems .
- Jamming pod components such as receivers , TWT , technique generator can be independence of aircraft processor, allow old fighters to carry same jamming systems that the newest aircraft capable of.
- Due to bigger size, jamming pod often have bigger transmitting antenna and more power available compared to FOTD decoys and air launched decoys ,as a result they have higher effective jamming power and better directivity (gain).

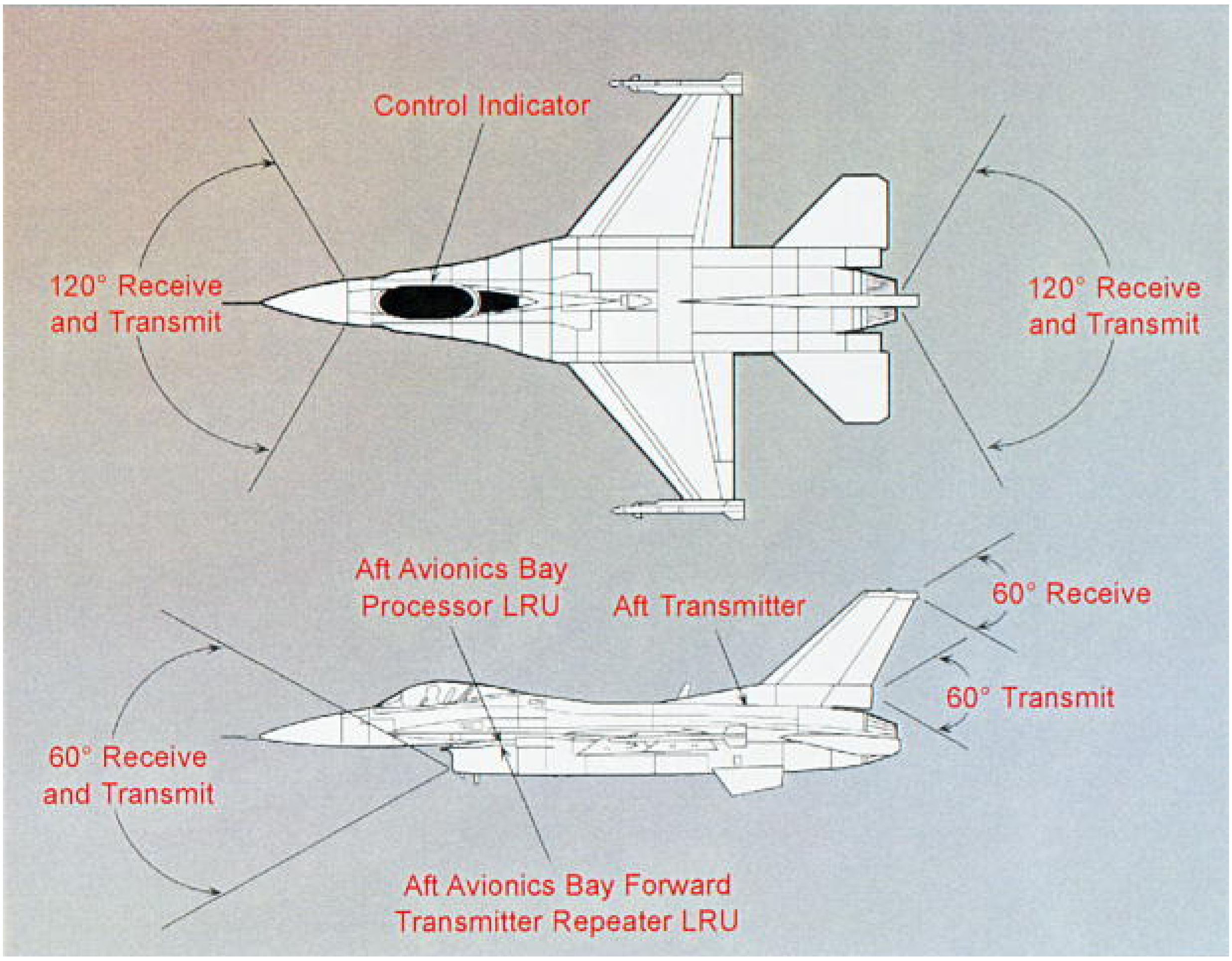
Disadvantages:

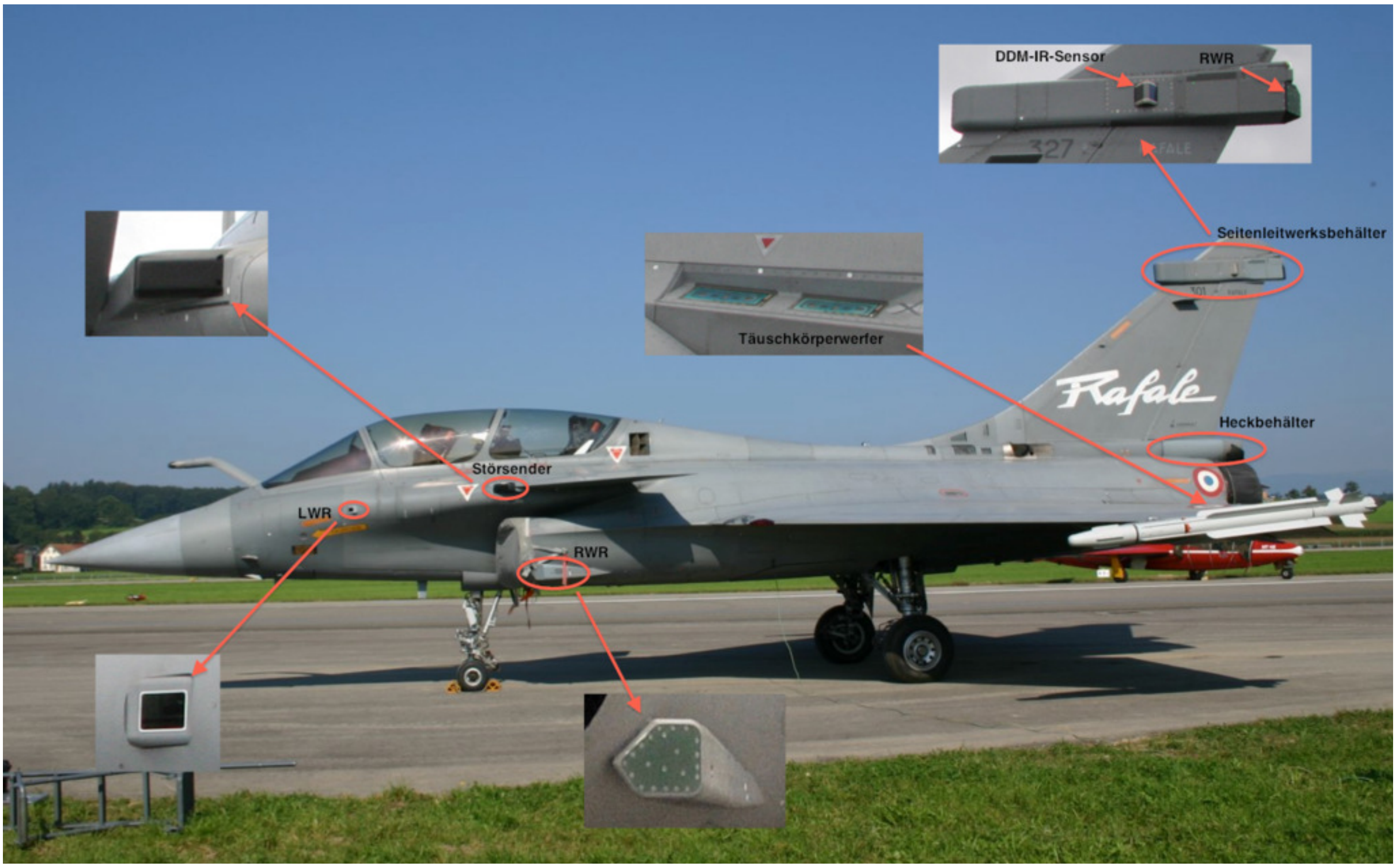
- Increase aircraft radar cross section and drag when being carried
- Reduce aircraft agility
- Depend on location (pylon or centerline station) , jamming pod often have blind spots above or under aircraft.

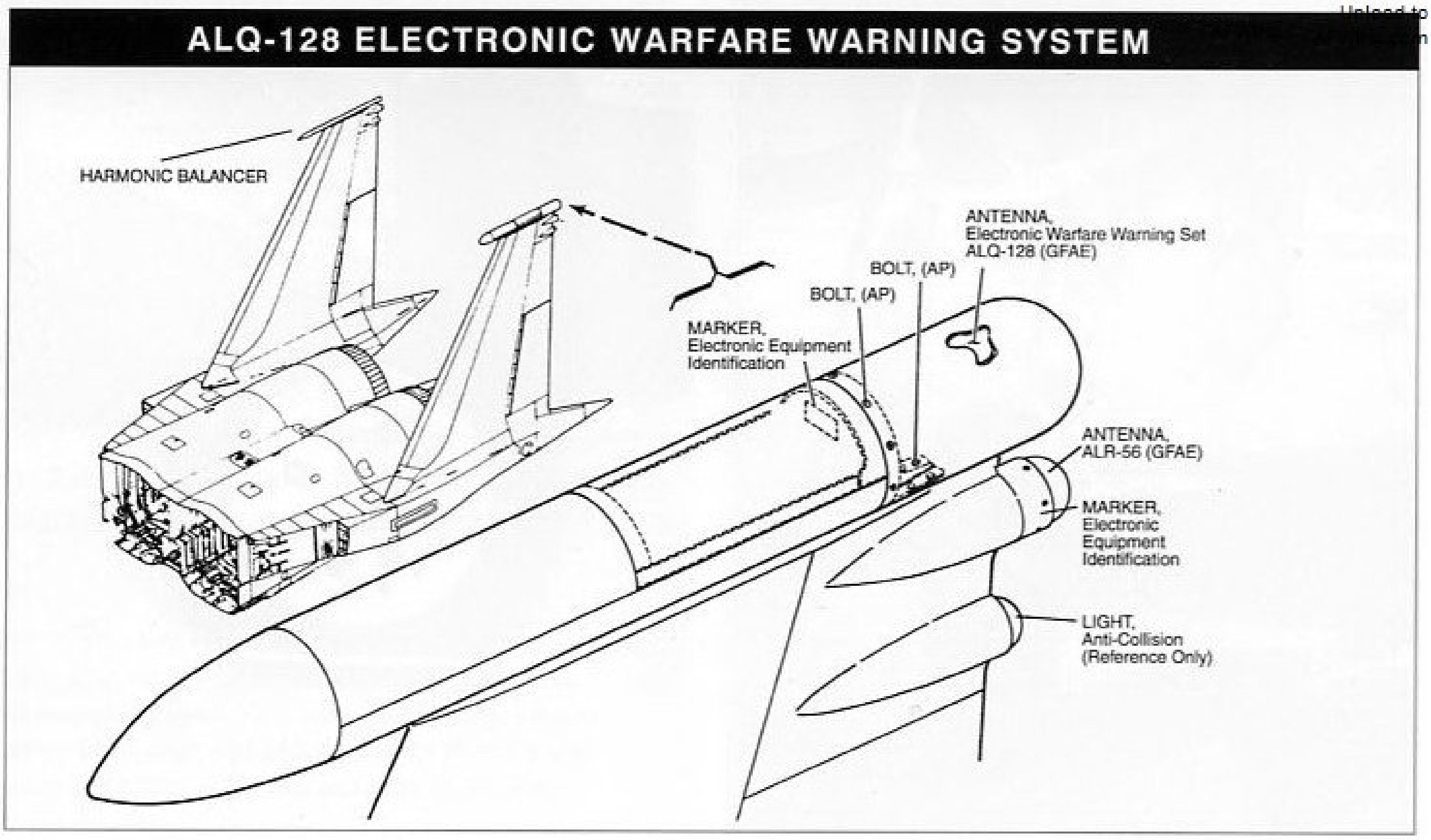
○ Transmitters are located on aircraft , thus, missiles in HoJ mode can be a threat

Internal Jamming System:

To free pylons for weapons and fuel tanks, some fighters have jamming system integrated inside their airframe , with processor and TWT placed completely inside fuselage while receivers and transmitters are located along vertical tail fins or on aircraft nose (in some rare case jamming system are located inside aircraft pylons).







Advantages:

- 360 degrees coverage (most internal jamming systems do not have any blind spot)
- Internal systems thus do not affect aircraft's weapon load, radar cross section or drag.
- Impact on aircraft's agility is small (due to weight)

- High power available for transmitters .

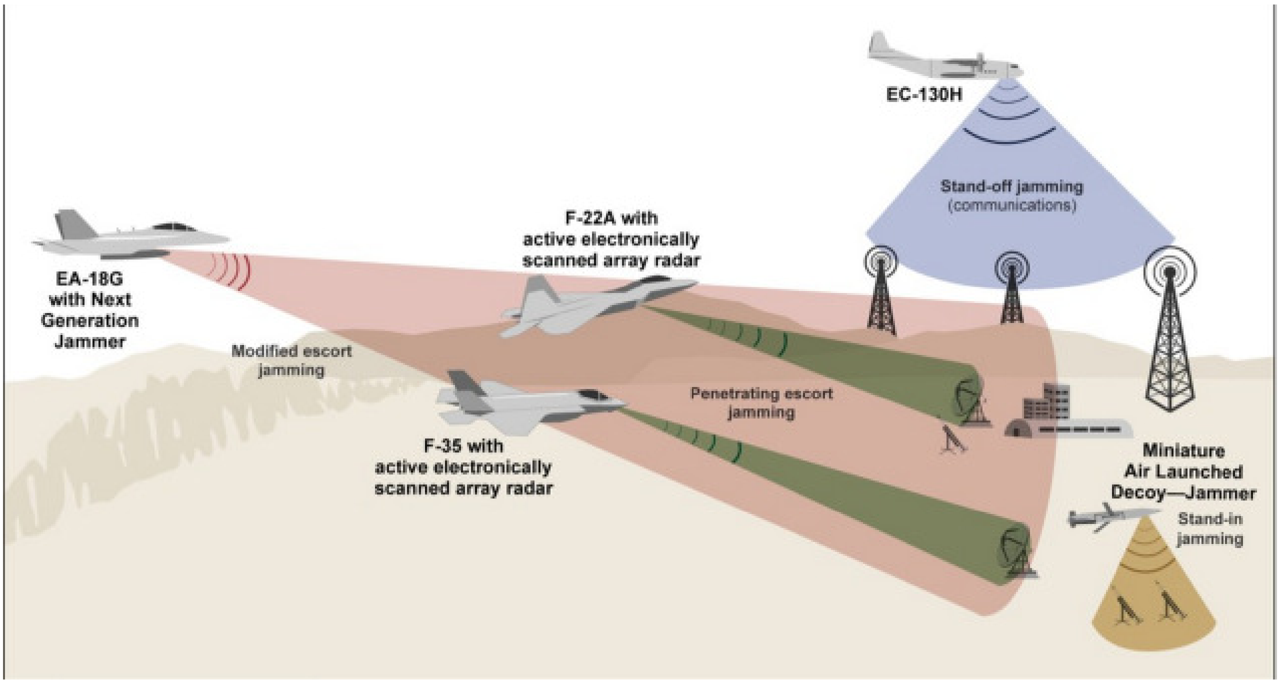
Disadvantages:

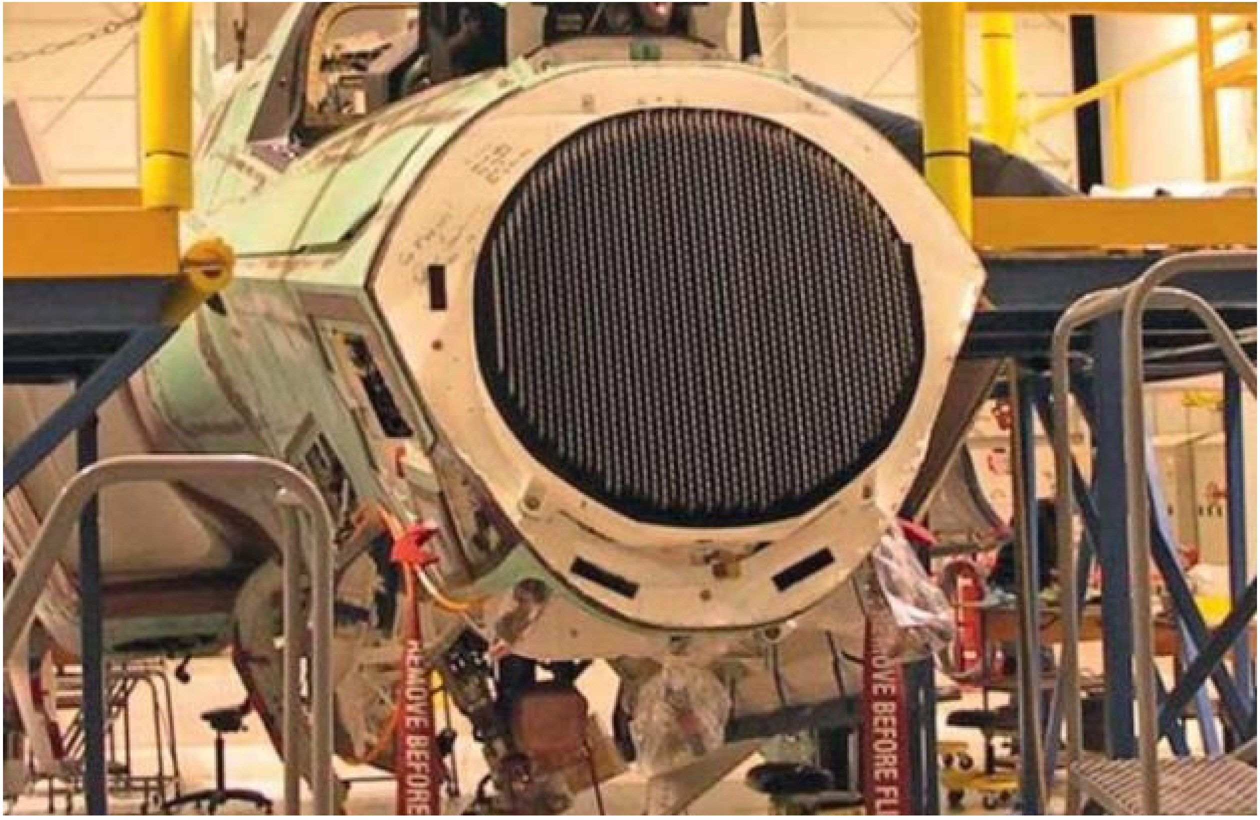
- Systems upgrade depending on aircraft's development cycles , thus slower upgrade rate and less flexible compared to off-board jamming system.
- Limited space available leading to small transmitters/receivers aperture , thus lower gain compared to sophisticated ECM pod like ALQ-99 or NGJ or fire control radar.
- Transmitters are located on aircraft , thus, missiles in HoJ mode can be a threat

<u>**Active Electronically Scanned Array Radar as Jammer:**</u>

Unlike traditional mechanical scanner array radars which have a single transmitter and receiver ,an active electronically scanned array (AESA) radar composed of numerous small solid-state transmit/receive modules, this allows the AESA to produce numerous simultaneous "sub-beams" at different frequencies .An AESA radar steer it's beam by sending separate radio waves (with appropriate delay) from each T/R module so that they interfere constructively at certain angles in front of the antenna aperture , this method help it focus the beam better (higher gain) than traditional parabolic radar ,and because everything are done electronically , AESA radar have much higher scanning rate too. Due to AESA radar unique characteristics , on some fighters (F-35 , F-22 , F-18E/F) , their fire controlled radars are used not only to locate and track enemy forces but also to jam enemy's radar , attack enemy's network and stream data at high speed.

Using fire control radar as jamming system is a unique case of internal jammer , the main different from a normal internal jamming system set up is transmitters aperture size.





Advantages:

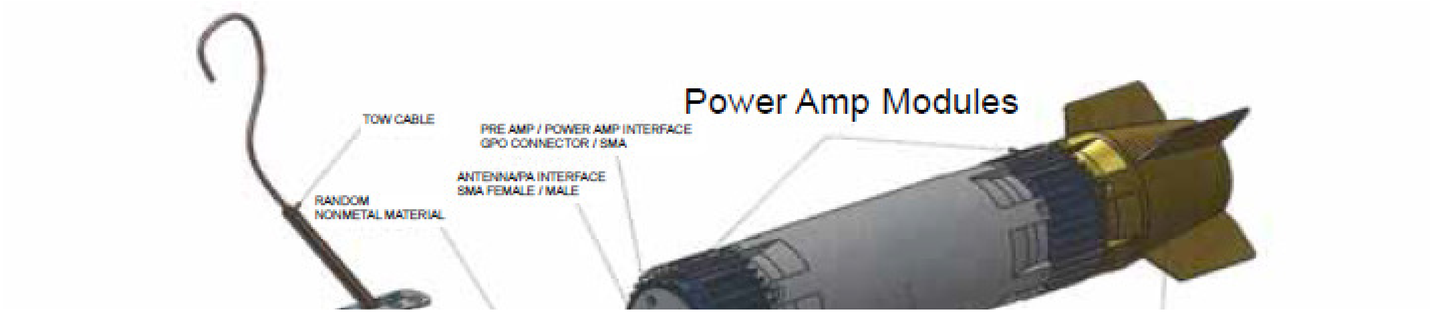
- More power available to transmitters compared to others configuration (ECM pod or normal internal jamming system)
- Superior aperture size to others configurations leading to much better directivity (better focus of jamming power)
- All components are internal thus do not affect aircraft's weapon load , radar cross section or agility

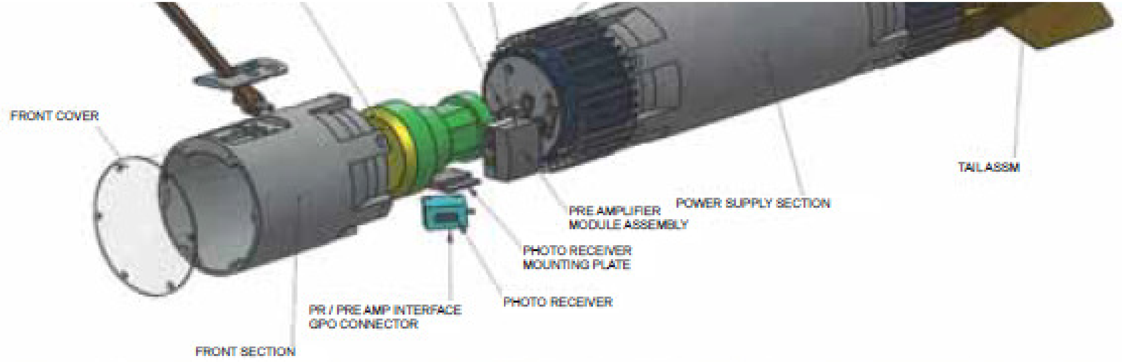
Disadvantages:

- Jammer has limited coverage : mainly frontal direction (equal to radar coverages)
- Limited frequency coverages : mainly X-band (from 8-12 Ghz)
- Transmitters are located on aircraft , thus, missiles in HoJ mode can be a threat

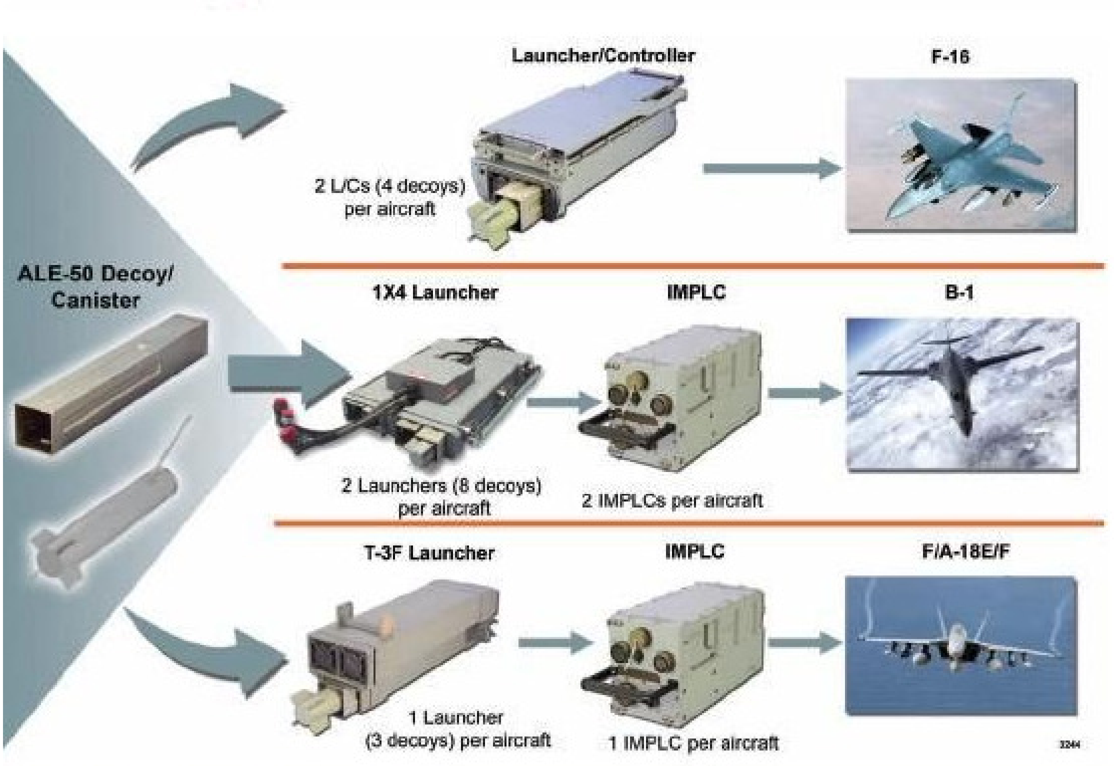
Towed Decoys:

The towed decoy was developed by the Naval Research Laboratory in the early 1980s. The core of towed decoys is a transmitter that amplified and retransmit all signal it received thus it appear like an attractive target with high RCS on adversary radar. When deployed, the decoy is towed behind the host aircraft, protecting the aircraft and its crew against RF-guided missiles by luring the missile toward the decoy and away from the intended target. In layman term , towed decoys are small transmitters being drag behind aircrafts.





Solid state towed decoy prototype with a pair of GaN solid state amplifiers.



Advantages:

- Decoys are towed behind aircraft with a cable so they move at the same speed as parent aircraft , as a result doppler effect does not help distinguish decoys from the real target.
- Towed decoys are often stored within wing pylons ,wing tip pod or aircraft fuselage thus do not affect aircraft weapons load

Disadvantages:

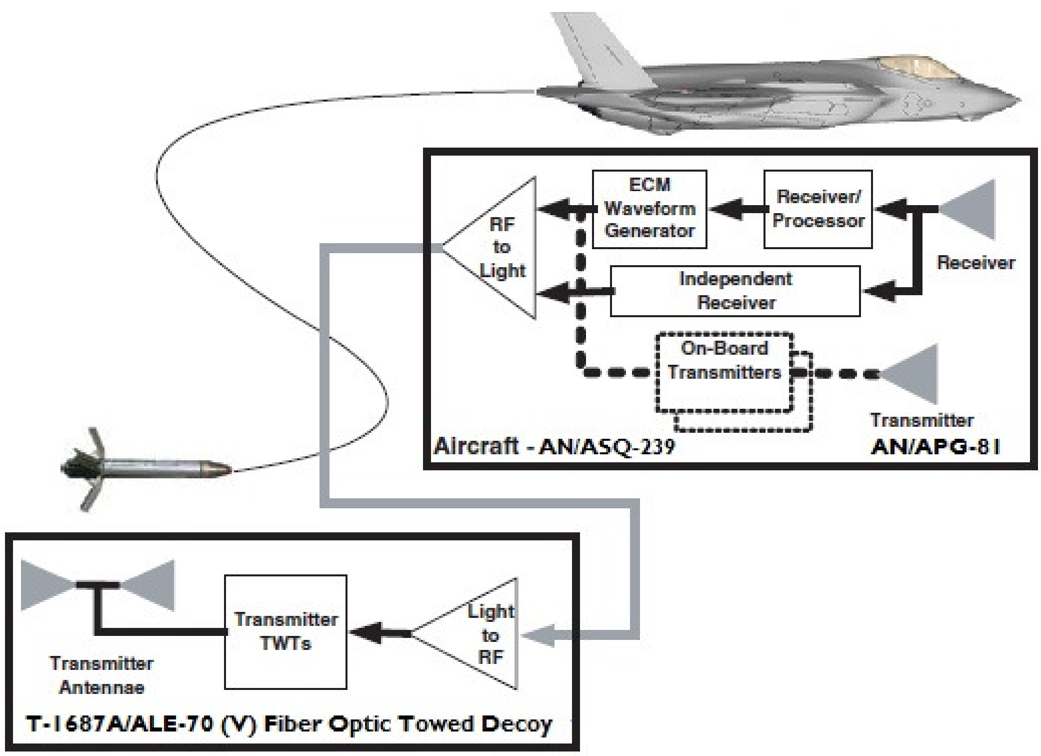
- After deployment decoys stay at a distance and connected to aircraft by a cable , thus limiting aircraft agility to low G maneuver.

- Decoys are towed thus it will always stay behind the real platform hence, missiles with 2-ways datalink or command guide can render towed decoy ineffective (because adversary SAM operator, pilot can choose which target for missiles to attack).
- Towed decoys rely totally on it's own internal component (processor, battery,and antenna) thus lacking the processing , jamming power , and directivity of ECM pod or aircraft internal ECM system.

Fiber optic towed decoys (FOTD):

Fiber optic towed decoys are upgraded variants of towed decoys. While traditional towed decoys rely totally on it's own electronic components to response enemy threats, fiber optic decoys have a fiber-optics connection allow it to rely on aircraft on-board radio frequency countermeasures system.Aircraft onboard electric warfare (EW) system is designed to receive radar signals from potential threat emitters via antennas on the forward and aft sections of the aircraft and to generate an electronic countermeasures response to the threat. Jamming may use either onboard transmitter (jamming antenna on aircraft) or the off-board transmitting capabilities of the FOTD decoy. For the off-board response, a jamming signal is generated by onboard EW equipment and provided to a decoy towed behind the aircraft for amplification and transmission. To reach the decoy, the signal is converted to light and transmitted down a fiber-optic link to the decoy. In the decoy, the light signal is converted back to RF, amplified, and transmitted using antennas integral inside the decoy. While antique towed decoys often only capable of amplifying and retransmit adversary radar signal , modern fiber optic towed decoys can transmit any and all signal that the aircraft's onboard countermeasure system capable of generating (from simple noise jamming techniques to complex deceptive jamming techniques)

Example diagram of FOTD systems:



Advantages:

- Decoys is towed by aircraft thus cannot be distinguished by Doppler effect
- Thanks to the fiber optics link with aircraft's onboard electric warfare system , the decoys is capable of generating very complex jamming signals
- Provide safety for carried aircraft when facing missiles in Home on Jam mode

Disadvantages:

- After deployment decoys stay at a distance and connected to aircraft by a cable , thus limiting aircraft agility to low G maneuver.
- Due to small size (antenna and TWT) , FOTD lack the jamming power of ECM pods and aircraft internal jamming systems

<u>About HOJ</u> : For modern radio guided missiles , if at any point during the missiles time-of-flight the target starts to use electronic counter-measures , the missiles can switch its tracking mode to home-on-jam , When this occurs the missiles homes in on the direction of the jamming signal, guiding it to the point where the

onboard radar 'burns through' the jamming and re-acquires the radar. When in the home-on-jam mode the missiles interlace the active pulses of the radar with passive guidance from the home-on-jam equipment.The HOJ mode does not provide as good a Pk the normal active guidance however because missiles cannot determine target velocity or distance from target , they are unable to perform lead intercept (missiles range in this mode is limited too because missiles cannot follow a ballistics arcs to conserve energy) .

Air Launched Decoys:

As radars getting more sophisticated and powerful , it get harder and harder to trick or overwhelm air defense with electronic jamming alone.Thus air-launched decoys were created to clutter up a radar screen with false targets making it easier for an attacker to get within weapons range and neutralize the radar.The concept is fairly simple , air launched decoys are small unmanned aerial vehicles , they carry signature augmentation subsystem such as Luneberg lens to mimic radar cross section of military aircraft along with GPS or inertial navigation system to help them follows pre-planned route (most decoys can be programmed with around 100 way points or more) .Decoys are intended to deceive a radar operator into believing that they are actually aircraft .Early air launched decoys such as ADM-141 TALD lacking internal engine thus they can only glide and have easy to predict trajectory.However , modern air-launched decoys such as ITALD , ADM-161 MALD are equipped with a turbojet engine (or rocket engine in case of AQM-37) , helping them reach much longer distance distances , cruise at high subsonic speed , climb and perform low G maneuvers.Latest air launched decoys such as MALD-J can even carry active jammer and 2 ways datalink system .Most modern air-launched decoys are compatible with MIL-STD-8591 14 Inch (35.56 cm) suspension lugs , 1760 interface connection or unpowered thus, they can be carried by a wide range of military aircraft (any aircraft capable of carry M-82 bombs).

A-4 and AQM-37

F-16 carries 2 AQM-37C

MALD-J on F-16 Triper Ejector Rack

MALD-J decoy in flight

Advantages:

- Distinguish between air launched decoys and real aircrafts is a challenging task for every radar but the latest one, and even with the most modern radar, it is impossible to discriminate between the decoys and cruise missiles.
- Can be programmed with high number of way points , and fly completely independent of launching platform after deployed thus allow flexible mission planning
- Very long range (around 400-900 km)
- Some decoys can carry communication and jamming system allow them to perform cooperative