ADVANCED CHAFF USAGE IN MODERN EW

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***Abstract*— This article describes the current situation in the area of electronic warfare. Aircraft protection can be greatly utilised not only in military but also in civilian applications. Active radar signal jamming methods are costly and therefore, aircraft protection using Chaff jamming increases efficiency, application variability and makes it affordable. However, use of Chaff is restricted or even forbidden in many countries due to its environmental risks caused by the applied materials. Article describes computing of Chaff RCS and RCS development in the air volume. Also particular self-defence technique is described.**

Keywords— Chaff, Jamming, Self Defence

I. INTRODUCTION

CHAFF is "strips of lightweight metal or metallic materials that are dispersed in large numbers (bundles), that can be into surveillance or observation volume of radar to reflect impinging signals and simulate a true target." It typically consists of strips of aluminium foil or metal-coated fibers. Each bundle of Chaff may contain thousands of individual reflectors whose lengths are related to the wavelength of the radar. Chaff for used in HF and VHF bands is called rope (or rope Chaff). As a passive electronic countermeasures technique, Chaff may be used in three distinct ways [1] [2] [3]:

1) A localized Chaff puff or burst can simulate a true target, serving as a decoy to radars which do not have a Doppler clutter rejection capability. Contributing to overload in the data output. [1] [3][4].

2) A Chaff corridor trail behind the lead aircraft in a raid, or can be fired via rockets from the lead aircraft, hiding within the corridor [1] [3].

3) A Chaff cloud may be dispensed over a large region, masking the actual attack corridor of a subsequent raid [1] [3].

Chaff dipoles are Chaff elements, typically lightweight metal (e.g., aluminium) or aluminium plated glass or Mylar dipoles. These Chaffs are dispensed in the atmosphere to reflect radar energy imitating the real target with large RCS. The Chaff dipoles are intended to resonate at the frequencies of victim radars, requiring that the length of the dipole be about one-half radar wavelength. Often the dipoles in a package are cut to different lengths to cover an entire radar band or several radar bands [1].

The methods used to disperse Chaff have evolved over the years, from basic ejection out of airplane windows, to launching with spring-loaded or pneumatic machines. Current the services used to disperse Chaffs are: 1) pyrotechnic charges, 2) rockets, 3) mortars, 4) air flows, 5) motors. Chaff is ejected either mechanically or pyrotechnically. Mechanical ejection uses small foil laminated cardboard boxes (2.8 by 4.8 by 0.8 inches) that are torn open during ejection. Debris from the cardboard boxes consists of the opened box, two high impact polystyrene plastic support pieces (2.75 by 4.75 by 0.06 inches), and paper wrapping for each dipole cut. Cardboard specifications have changed from virgin kraft paper to recycled kraft paper, due to its it biodegrade efficiency. The sealing adhesive for these boxes is aqueous type polyvinyl acetate and a felt spacer [5]. Figure 1 depicts an example of Chaff.

Fig. 1: Example of Chaff

Pyrotechnic ejection uses hot gases generated by an explosive impulse cartridge. The gases push a small plastic piston down a Chaff-filled tube 8 inches long with a 1 inch square cross-section. This ejects a small plastic end cap, followed by the Chaff fibers. The tube remains in the aircraft. Debris that is ejected consists of two 1 inch square pieces of plastic l/8 inch thick (the piston and the end cap) [5].

Chaff cartridges must demonstrate ejection of 98 percent of the Chaff in undamaged condition, with a reliability of 95 percent at a 95 percent confidence level. They must be able to withstand any combination of environmental conditions that might be encountered during storage, shipment, and operation [5].

Motors feed Chaff from rolls of about 40 pounds through cutters carried on some aircraft to produce either bursts or a continuous stream. The continuous stream technique, called saturation Chaff, may be used by aircraft to cover a large area. By 2005 or 2006, the Army also planned to use saturation Chaff to mask vehicle and troop movements. Using a cutter, 360 pounds of Chaff from nine 40-pound rolls can be deployed in 10 minutes. Depending on the method and the number of aircraft, such releases could disperse billions of fibers. The B-52 can carry about 750 seven-ounce boxes of Chaff; each box contains up to 11 million fibers that can be expelled continuously or in bursts [5][6].

II. RADAR CELL AND CHAFF

A. Radar resulution cell

The range and angular (Azimut and Elevation) resolutions lead to the resolution cell. The meaning of this cell is following: unless one can rely on eventual different Doppler shifts it is impossible to distinguish two targets which are located inside the same radar resolution cell (RRC).

Example is depicted on fig:2 One usually assumes that the impulse volume is fixed by the aperture angle φ (or half power half power (-3 dB) angle) of the antenna beam and the range resolution ΔR corresponding to:

$$\Delta R = ct_i/2. \quad (1)$$

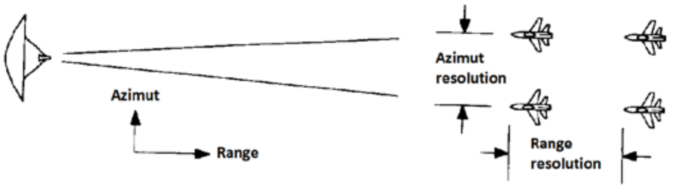

Fig. 2: 2D resolution cell [6]

B. CHAFF Scattering

Electromagnetic scattering from cloud dipole reflectors at high frequencies is fully resonant and in this regard differs from the mechanism of scattering associated with a mist or dust. A typical dipole cloud reflectors may contain several hundred million dipoles. If you divide the cloud dipole reflectors on a large number of cells, we can average the response dipoles in the cell, so that we can consider that "averaged" dipole causes backscatter towards the radar (it's a response RCS) plus an omnidirectional component variance, which is responsible for the observed loss of RCS.

This model allows the calculation of scattering dipoles losses in the cloud RCS dipole reflectors ray-tracing. The beam was monitored from each cell in a cloud of reflectors back to the radar. Backscatter (RCS) associated with each cell is reduced by the omnidirectional scattering associated with each second cell in response to the path along the radar beam. If we keep the number of cells is constant, then, as the size increases cloud strips, the density of the dipoles in each cell decreases. This has the effect of reducing the cloud RCS dipole reflectors and subsequent reduction in scattering losses. Detailed calculations are complex, but verify that the growth of cloud RCS dipole reflectors may be rounded empirical equation:

$$RCS = RCS_{\max} \cdot \left[1 - \exp(t/\tau)\right] \quad (1)$$

where RCS is a radar cross-section at time t, RCS max is the maximum (fully dispersed) RCS cloud Chaff and τ is the time constant.

C. CHAFFs leanding

The average rate of descent of the cloud dipole reflectors measured by radar is around 0.3 m/s. However, this number is associated with typical good weather conditions that occur in the coastal areas of the UK. Significant changes are possible according to local conditions, especially in strong thermals and / or descending streams. They were observed deviations between 0.1 and 1 m/s. In conditions of high humidity and rainfall will be a high rate of descent due to adhesion of water droplets to individual dipoles. While in dry summer weather, when high (climbing) currents of warm air will descent speed lower or even no (or may even appear climb instead of falling, when the cloud bands persist in the atmosphere for several hours and is carried by upper wind). There is a risk in carrying out the tests in the summer, because the winds can drift cloud bands in the vicinity of radars to control flight movements).

III. ADVANCED CHAFF USAGE

A. JAFF

JAFF (jammer + Chaff) is the technique of using jammer-illuminated Chaff, where previously ejected Chaff is illuminated with a coherent noise or deception signal to impose a suitable Doppler frequency on the radar return. In the normal situation, Chaff is strongly attenuated by MTI, but when illuminated by the jamming signal the resulting echo falls outside the Doppler rejection notch. Such a technique can be used for self screening and its aim is to produce relatively cheap off-board decoys endowing Chaff cloud reflection with a proper Doppler shift (Fig. 3). Sometimes this technique is termed CHILL (Chaff, illuminated) [7].

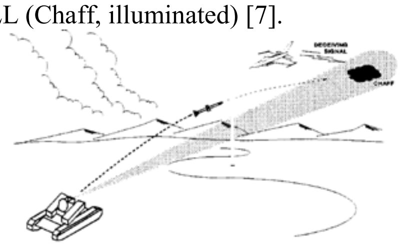

Fig 3: Jammer-illuminated Chaff [7]

B. Chaff theme

Dipole reflectors achieve interruption of surveillance in elevation, or more commonly in the direction or extent, disruption mono-impulse radar followers arising from the formation of one or a series of false targets close to the real goal, while all the RRC radar. In case ASPC is important to realize that the time available for creation of these false targets or decoys is very short (tens of milliseconds at the speed of the airplane). For example, in a typical system missile air defense short-range (SHORAD) with a beam width 2° angle and elevation with a pulse length (or gate range) of 400 ns at a typical range of search targets 6 km, the size of the RRC was about 210 meters in the distance (or a plane) and 60m in depth (or range). When the aircraft is monitored at the center of RRC, distance from the airplane to the edge of the RRC (at optimal transition path diagonally across the edge RRC) is 108 meters. It is a space in which an ASPC develop if it is to be effective in disrupting radar tracking function. So if we accept that the developed dipole reflectors lose all forward speed almost immediately after the launch of the dynamics of deployment, RRC (and radar coverage of this space) move at the speed of the target airplane or helicopter. For an airplane with a speed of 232 m/s, this time is 465 ms; in helicopter with a rate of 46 m/s is 2.33 s. Therefore, when developing programs for interrupting radar tracking using dipole reflectors is important to realize geometry and deploy real life for ASPC. The example given concerned a range of 6km; it should be appreciated that the usage time will be reduced, the closer the target to radar and vice versa. Similarly, it will decrease the bandwidth.

C. Manoeuvre

In any case, to avoid problems relating to sophisticated MTI / pulse radar using the Doppler effect, and that the response to a dipole reflectors not reduce about 30 - 40 dB (depending on the quality of the filter utilizing Doppler radar) with respect to the response of the airplane prior to discharge strips pilot should perform the correct maneuver. In this way, the airplane can submit enemy radar very low frequency Doppler radar and seriously weaken the filter response dipole reflectors. Dipole reflectors are then successfully launches and eventually the airplane can resume its course as indicated on Figure 4.

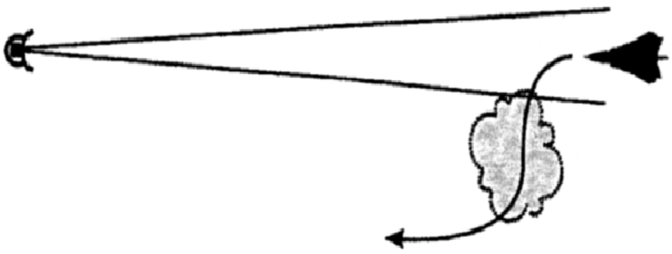

Fig 4: Chaff + maneuver

The aircraft is maneuvering to create a low Doppler frequency, launching tape, a large RCS divert gate-range radar.

IV. RESULTS

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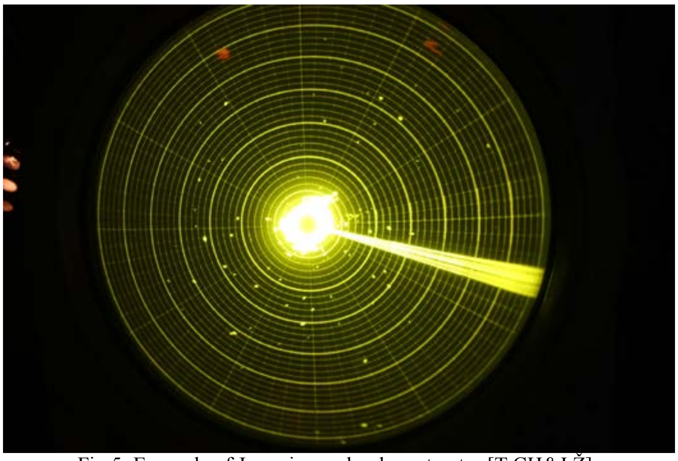

Fig 5: Example of Jamming and radar extractor [T.CH&J.Ž]

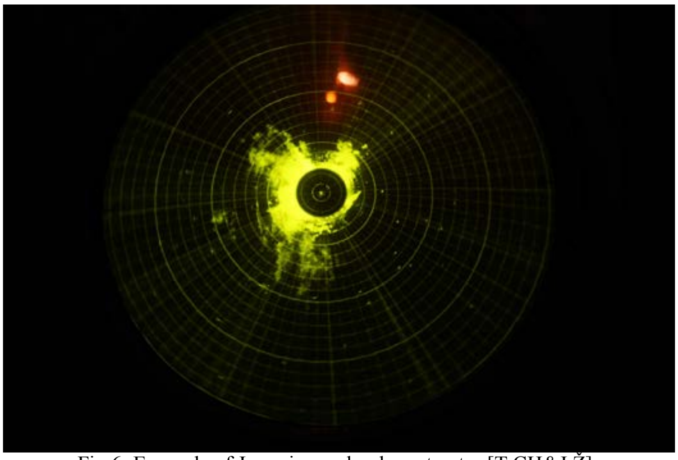

Fig 6: Example of Jamming and radar extractor [T.CH&J.Ž]

V. Conclusion:

Despite the fact that Chaffs are restricted or even forbidden in many countries due to its environmental risks caused by the applied materials. Chaffs have got significant role in modern electronic warfare.

The prevailing opinion, that they can be easily overcome by MTI filtering, is broken by JAFF technique. Impulse Doppler Radars lost their ability to track targets behind large Chaffs clouds.

In addition, proper aircraft manoeuvre, will equalize Doppler velocity in limited time frame, which makes all composition even more effective.

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