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Recent Research into Reducing Birdstrike Hazards

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Summary

In the aftermath of the 1995 AWACS birdstrike tragedy, Wright Laboratory is accelerating its search for technologies to prevent serious birdstrikes. These studies represent a cooperative effort between the U.S. Air Force, the U.S. Department of Agriculture, members of the aerospace industry, and academia.

The research focuses on the active projection of sound to disperse birds from the flightpath. This includes infrasound, modulated radar, and discrete bands of noise normally associated with aircraft engines. Early results indicate that birds appear to respond to these sounds. Additional study is needed to determine if these sounds, used separately or in combination with other stimuli, convey a biological meaning to the birds sufficient to result in birdstrike reduction.

Passive infrared sensors systems are undergoing evaluation for possible application in locating bird targets that may threaten safe flying operations. Recent research suggests that the long-wave infrared systems may provide the needed sensitivity and range to discriminate bird targets in an airfield environment, and possibly, during flight. Further research is underway to develop and optimize this capability.

(KEYWORDS: Control Methods; Sound; Infrasound; Engineering; Engines; Detection; Infrared; Bird Populations; Body Density/Weight; Testing; Substitute Birds)

1.0 INTRODUCTION

The events leading to the loss of an E-3 "AWACS" aircraft in September, 1995, have underscored the continuing need for technology development for the warning and control of bird populations on airfields. An USAF report of the accident noted deficiencies in the acknowledgement and management of an increasing population of Canada Geese (*Branta canadensis*) on the airfield (Anonymous 1996). These deficiencies suggest that there is a growing need for technology applications to warn aircrews and airfield management of the presence of birds hazardous to safe flight. Birdstrikes to USAF aircraft result in damage averaging $50 million per year.

Technologies developed to fulfill military needs can often be modified for other uses. This paper discusses the corporate USAF commitment to bring new, available technology to bear on this problem. The development of new, effective bird hazard management technologies or procedures will be passed along immediately to the commercial sector.

2.0 INFRARED SENSORS

The purpose of this research was to investigate the feasibility of using infrared (IR) sensor technology to image birds. Infrared sensor technology may have application in locating bird targets that pose a threat to safe flying operations. The quick development and application of such a capability could help identify dangerous situations for implementation of birdstrike avoidance procedures.

While a significant body of literature exists for using radar and visible light technologies to detect birds, very little has been published on using infrared (IR) technology to detect birds. Infrared detection systems could provide a low-cost, low maintenance and highly accurate method for detecting individual birds or flocks of birds that could present hazards to aircraft. These bird indications could then be used as part of a bird strike avoidance system to provide information on their location to aircrews, air traffic controllers, or airfield management personnel. An artificial intelligence system could be introduced to "alarm" situations needing prompt and specific attention.

2.1 IR System Components

A typical infrared detection system includes three interrelated components: the optics used to focus the infrared energy on a sensor, the infrared sensor itself, and the electronics/computer used to control the optics and interpret the IR data.

The optics of an IR detection system consists of the lens and a filter. The choice of lens system determines the field-of-view required for the sensor system and the filter determines the IR wavelength that will be examined. In essence, the full IR spectrum is segmented into three regions (Figure 1) that are not complicated by atmospheric interferences: short wavelength IR (2-4 microns), medium wavelength IR (5-7 microns) and long wavelength IR (8-12 microns). The long wavelength region is expected to achieve the greatest resolution for our IR sensor system because it is less sensitive to reflectance from nearby terrain.

Sensors are available in two basic types: staring and scanning. Staring arrays are a matrix of IR detectors typically rectangular, such as 128x128 detectors. Scanning sensors are usually one or two rows of 1024 or 2048 sensors. In a staring array sensor system, the optics are usually fixed and the entire field of view is imaged instantaneously. In a scanning system, the field of view is divided into overlapping segments and the optics move so that segments are sequentially imaged onto the sensor. Thus, the optics and sensor system are closely interrelated. Sensors are made of many different materials. The property of the material governs the wavelength to which the sensor responds. Typical materials used for sensors include Mercury Cadmium Tellurium (HgCdTe), Indium Antimony (InSb) and Platinum Silicon (PtSi).

The last component of an IR system is the electronic/computer component which varies according to the amount of processing that is required.

2.2 IR Feasibility Study

For our feasibility study we used a medium wavelength IR (MWIR) sensor system currently used to locate missile targets many miles away. Birds have been detected in flight against an ocean background at approximately six kilometers with medium wave (3.8-4.1 microns) IR imaging research sensors (Stone, Takken and Brown 1996).

Several species of birds were imaged--both caged and in the wild--to determine the sensitivity of the IR apparatus and to approximate detection ranges (Table 1). Though useful IR images could be obtained, the MWIR was not sensitive enough to show birds at a reasonable distance for implementation of bird avoidance measures. This finding suggests that long wavelength IR (LWIR) may provide the best sensitivity and range to discriminate bird targets in an airfield environment.

TABLE 1. Imaging of birds using medium-wave infrared system

Common Name	Species	Results
Red-tailed Hawk	*Buteo jamacensis*	caged; strong image at 160 feet
Rock Dove	*Columba livia*	caged; image at 160 feet
Merganser	*Lophodytes cucullatus*	caged; faint image at 160 feet
Bonaparte's Gull	*Larus philadelphia*	caged; no image at 160 feet
Mallard	*Anas platyrhynchus*	wild; faint image at ~30 feet
Canada Goose	*Branta canadensis*	wild; faint image at ~200 feet

The follow-on project will examine off-the-shelf, LWIR system components for detection of birds. We will document several possible LWIR system component options to determine the best performance and price for a complete LWIR system capable of detecting birds at short range. If feasible, a prototype system will be constructed and evaluated.

3.0 ENGINE NOISE

The purpose of the engine noise research is to determine if certain, discrete engine frequencies can be used to warn birds about the aircraft. Seaman (1967) reported on studies conducted by the U.S. Air Force using jets and sounds created in the laboratory that caused flocks of blackbirds to dissociate. During an experimental monitoring to survey birds using acoustic methodology, Fazio, et. al. (1994) showed apparent sound frequency overlaps at about 3000 Hertz for Boeing 747 engines and gull (species unknown) vocalizations.

Using birdstrike data maintained by the USAF Bird-Aircraft Strike Hazard Team, the authors identified some outstanding incongruities in USAF birdstrike data for certain airfields and aircraft types. For example, for over 500 KC-10 birdstrikes at Barksdale AFB, Louisiana from 1985-94, there exists an 80:20 (landing:takeoff) ratio of birdstrikes; the expected ratio should be closer to 50:50. This suggests that there may be some cues (perhaps aural) available to the birds during the takeoff that are not present during landing. If there are discrete, common frequencies that are present in both aircraft noise and bird vocalizations then what information do the birds receive from the sounds? Engine sounds are a likely source to begin the search.

Armstrong Laboratories' Noise Effects Branch (AL/OEBN) conducts noise research for the Air Force and maintains a library of USAF aircraft noise. Frequency spectra for the engine noise from a static KC-10 aircraft was obtained using the noise analysis system at AL/OEBN. These sounds are representative of takeoff power configuration and were collected at 10 degree increments from 0-20 degrees (Figures 2a-c). These spectra represent continuous peak values collected for engine runup.

Bird distress calls often are used to disperse certain birds by playing back these vocalizations over a loudspeaker. Distress tapes for several bird species and a composite distress sound ("Mega-stress") were obtained from the U.S. Department of Agriculture Animal Damage Control Office in Columbus, Ohio and the Denver Wildlife Research Center's Sandusky, Ohio Field Station (Table 2). Frequency spectra for the distress calls were obtained using the aircraft noise analysis system at AL/OEBN. These spectra represent frequency peak average values over the entire distress call (Figures 3a-g).

TABLE 2. Bird Distress Sounds Used in Analysis

Common Name	Species
Snowy Egret	*Leucophoyx thula*
Herring Gull	*Larus argentatus*
Ring-billed Gull	*Larus delawarensis*
Crow	*Corvus brachyrhynchos*
Starling	*Sturnus vulgaris*
Red-winged Blackbird	*Aeglaius phoeniceus*
Common Grackle	*Quiscalus quiscula*

The key frequency overlaps can be determined by combining the values for the specific frequency peaks for the engine noise and the bird sounds. Figures 4-6 (a-c) show the overlaps for the KC-10 aircraft runup for angles 0-20 degrees for the bird distress vocalizations. The data has been normalized so that the highest peak frequency combination (engine noise plus bird distress) possible is 100. The significance of especially strong frequency overlaps has not been determined (e.g., 2432 Hz for Herring Gull). It may be necessary to examine lower peaks which are similar for more than one species.

Engine noise may only provide part of the sound spectra from the aircraft. A flying aircraft generates other noises which emanate from the airframe, antenna, landing gear, flaps and other structures. Aircraft noise has been collected for many aircraft during low altitude fly overs; these sound spectra need to be collected for the KC-10 to determine if there are important frequencies to evaluate during actual flight. Other bird-aircraft mishap rates and the corresponding noise spectra will be examined as the information becomes available. Additional research is needed to determine if these overlaps are artifacts of the procedure used or if the engine sounds actually convey some biological meaning or warning to the birds. The birds may be responding to the interval "cadence" of distress calls as much as peak energies. Also, other aircraft configurations and bird species need to be considered. Other birdstrike databases need to be examined to determine if there exist other aircraft-birdstrike anomalies.

4.0 INFRASOUND

The purpose of this study was to confirm the ability of birds to sense low frequency sound (infrasound) and to study bird reactions to these sounds. Specifically, does infrasound provide a response which could be used to modify bird behavior thereby reducing the hazard to aircraft?

In a recent Air Force study (Genova and Castiglia 1995), infrasound was considered to be frequencies below 30 Hertz (Hz). Infrasound occurs naturally in the atmosphere and can vary in intensity from below 74 decibels (dB) to 120 dB. There are many natural sources of infrasound: earthquakes, volcanoes, meteor impact, auroras, severe weather, jet-streams, and orographically induced. Some species of animals use infrasound to communicate. It has been suggested that birds may use naturally occurring infrasound to avoid severe weather or as a navigation aid.

Similar to ultrasonic devices now available for bird control, infrasound generators could be positioned along a runway to affect birds within a certain radius. Hamershock (1992), in a review of ultrasonic bird repelling devices, found that these systems are basically ineffective at dispersing birds. It would be expected that the birds also would habituate to infrasound generators unless additional stimuli were provided.

5.0. MICROWAVE-AIDED DISPERSAL

There have been numerous, annecdotal observations over the years where animals seem to react to operational radars. Birds have been reported to dodge out of the radar "beam". Airborne radars were evaluated as a bird deterrent (Tanner, Romero-Sierra and Davie 1967; Tanner 1968) but the average power levels were prohibitive.

With the early radar systems, some aircraft pilots would turn on their aircraft weather radar when birds are present in the belief that the radar would help keep birds away. Some people can apparently "hear" the radar signal. Studies conducted by United States Veterans Administration Laboratories (Justesen 1975) indicated that modulation of the radar signal seemed to improve the ability to understand a message transmitted using the radar beam. It has not been determined what physiological process allows this phenomenon to occur. Average power of the radar systems does not seem to be as important a factor as is the rate of change and the amount of change in the radar pulse (Genova and Castiglia 1995). Peak energy needed to produce an audible microwave was given as 10 percent of the permitted (in the U.S.) safe exposure level (in 1975) for continuous exposure.

If the radar signal can be modulated with information that will "mean" something to the birds--such as, "Danger!"--then that could be a powerful tool in the efforts to clear birds from the path of aircraft. If birds can be provided an early warning of an approaching aircraft, the better their chances of getting out of the way, or of modifying their flight path to avoid being hit by the aircraft. A preliminary analysis has shown that if birds can be presented with an appropriate avoidance stimulus 4000 feet ahead of the aircraft, they could avoid even the largest aircraft below 1500 feet, either on take-off or landing (Genova and Castiglia 1995). Theoretically, modulated radar signals could provide a signal at distances exceeding 5000 feet in front of an aircraft. A study is underway to refine the research protocol and, if successful, to develop a prototype modulated microwave warning system.

6.0 BIRD AVOIDANCE MODEL IMPROVEMENT

The Bird Avoidance Model, originally hosted on a main-frame computer, has been used over a decade to provide military aircrews, flight schedulers and low-level (altitude) training route planners with information on the expected abundance of birds along specific flight paths away from the airfields. Flight decisions can then be made which will avoid bird-aircraft interactions. The bird avoidance model is continually undergoing improvement. In the late 1980's, the model was transitioned to a geographic information system format so that the contribution of habitat features that may affect the density of birds could be considered.

New bird species are added as detailed information becomes available. A species of particular interest is the Turkey Vulture (*Cathartes aura*) that is causes about one percent of the (approximately) three thousand birdstrikes and 40 percent of the incident damage to USAF aircraft each year. The movements of several populations of Turkey Vultures are being monitored with global positioning transmitters which are tracked via satellite. The transmitters relay the vultures' altitude, location and time. This information is used to generate risk maps for the vulture populations. Low-level route schedulers and aircrews will use these maps to choose their route and time of flight to avoid peak, potentially hazardous concentrations of vultures.

7.0 LITERATURE CITED

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FIGURE 1. Atmospheric inhibitors of infrared transmission

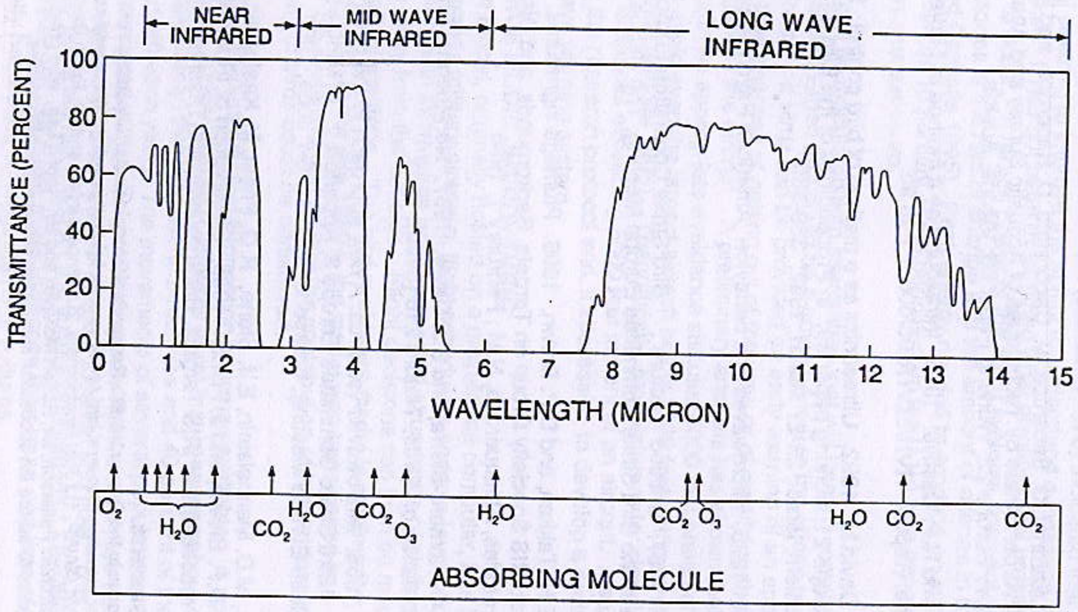


FIGURE 2a. KC-10 Ground Run-Up - Max RPM - 0 Degrees

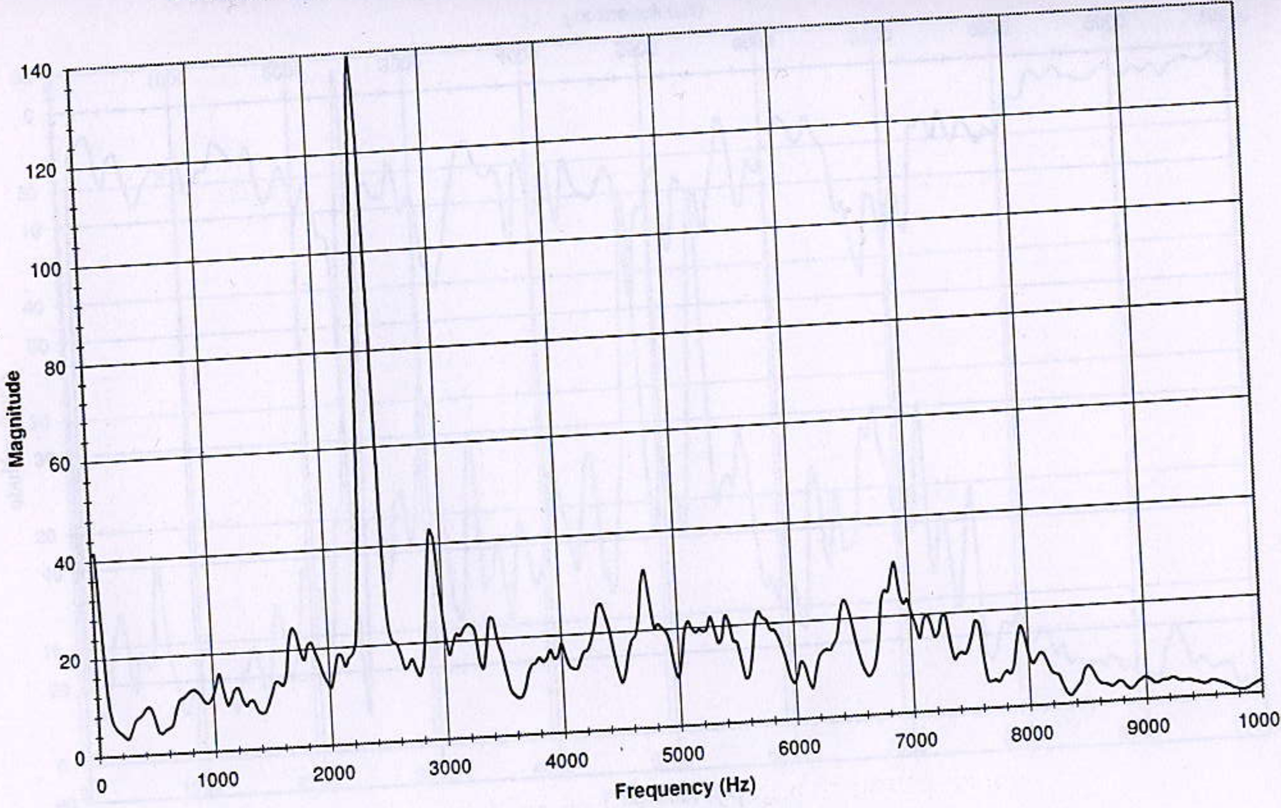


FIGURE 2b. KC-10 Ground Run-Up - Max RPM - 10 Degrees

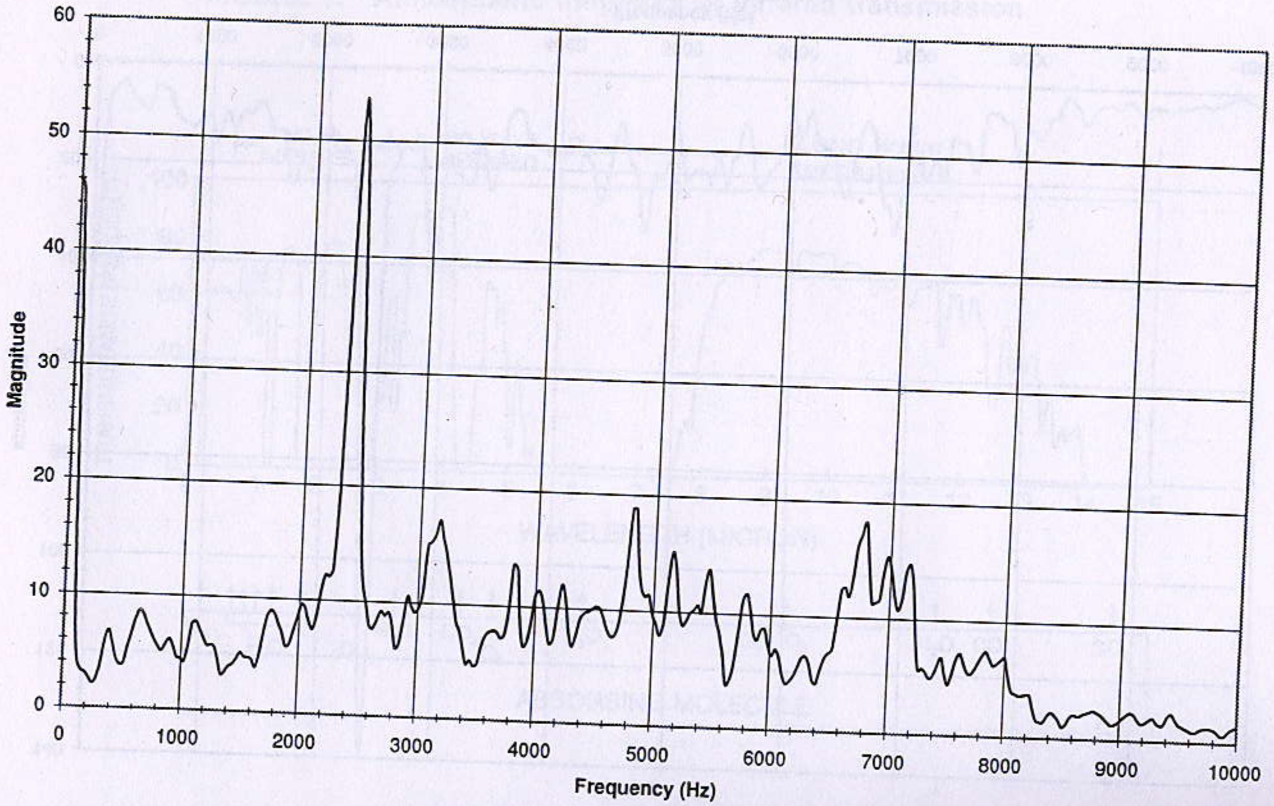


FIGURE 2c. KC-10 Ground Run-Up - Max RPM - 20 Degrees

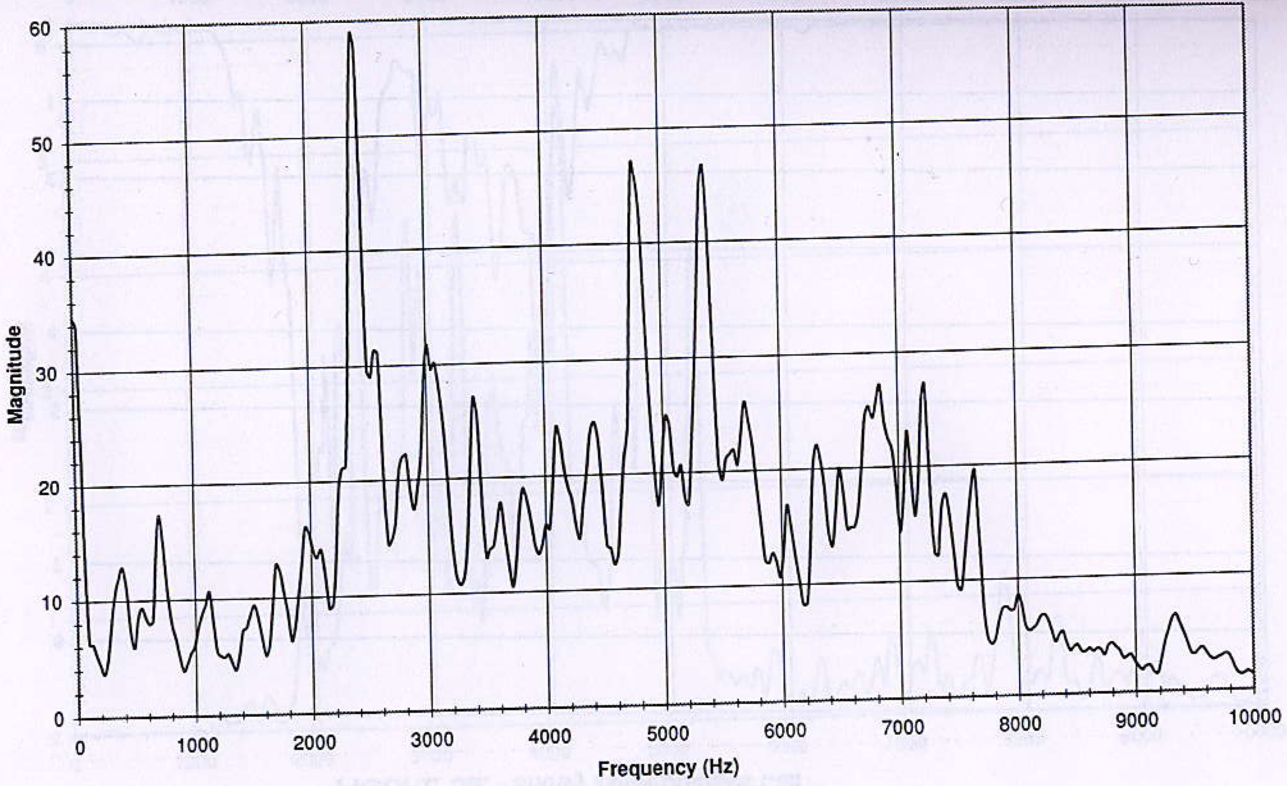


FIGURE 3a. Snowy Egret Distress Call

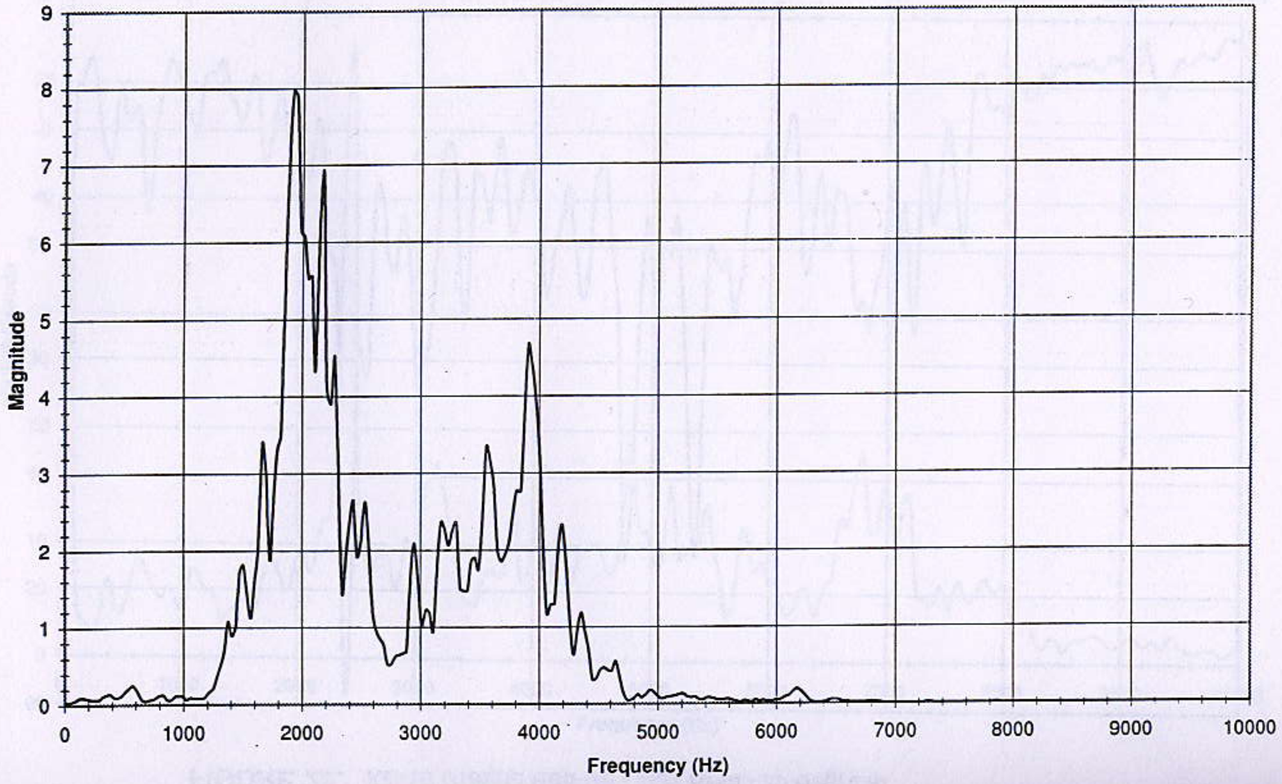


FIGURE 3c. **Ring-Billed Gull Distress Call**

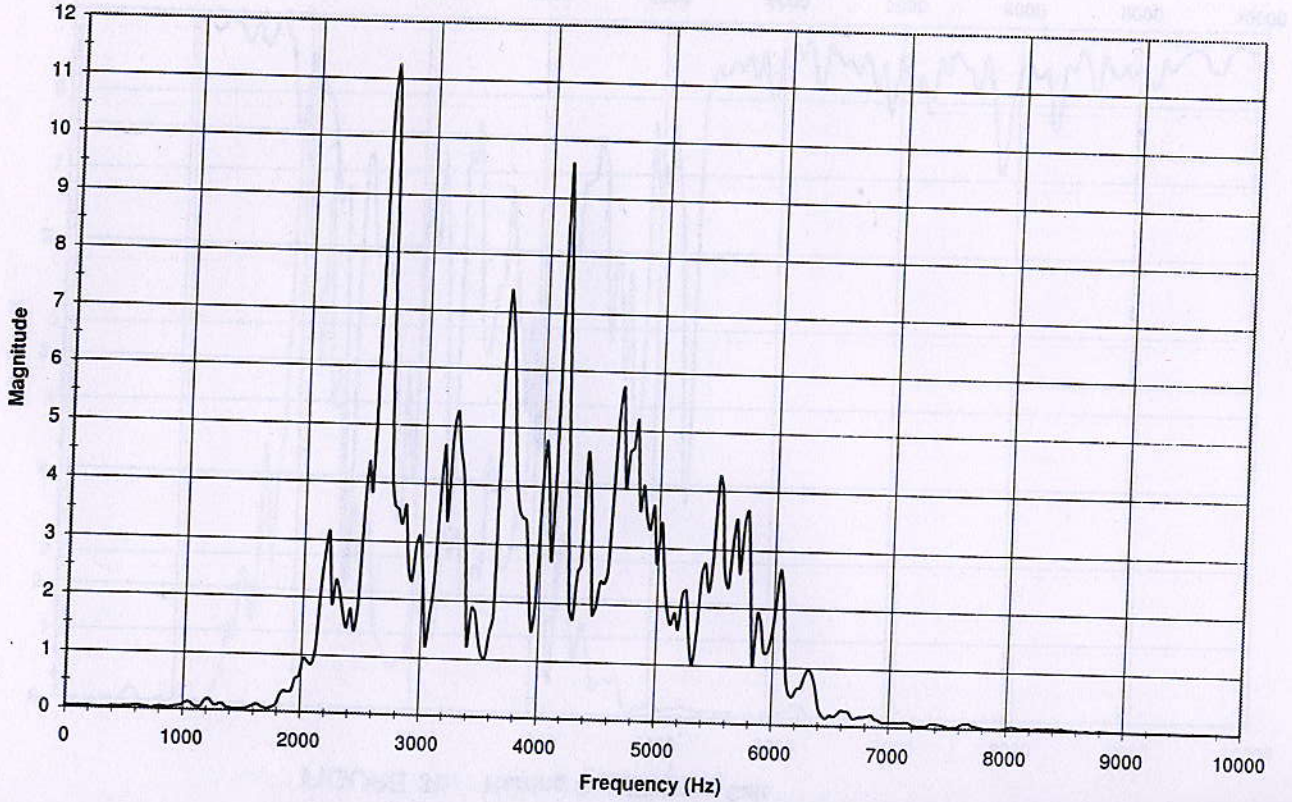


FIGURE 3e. **Starling Distress Call**

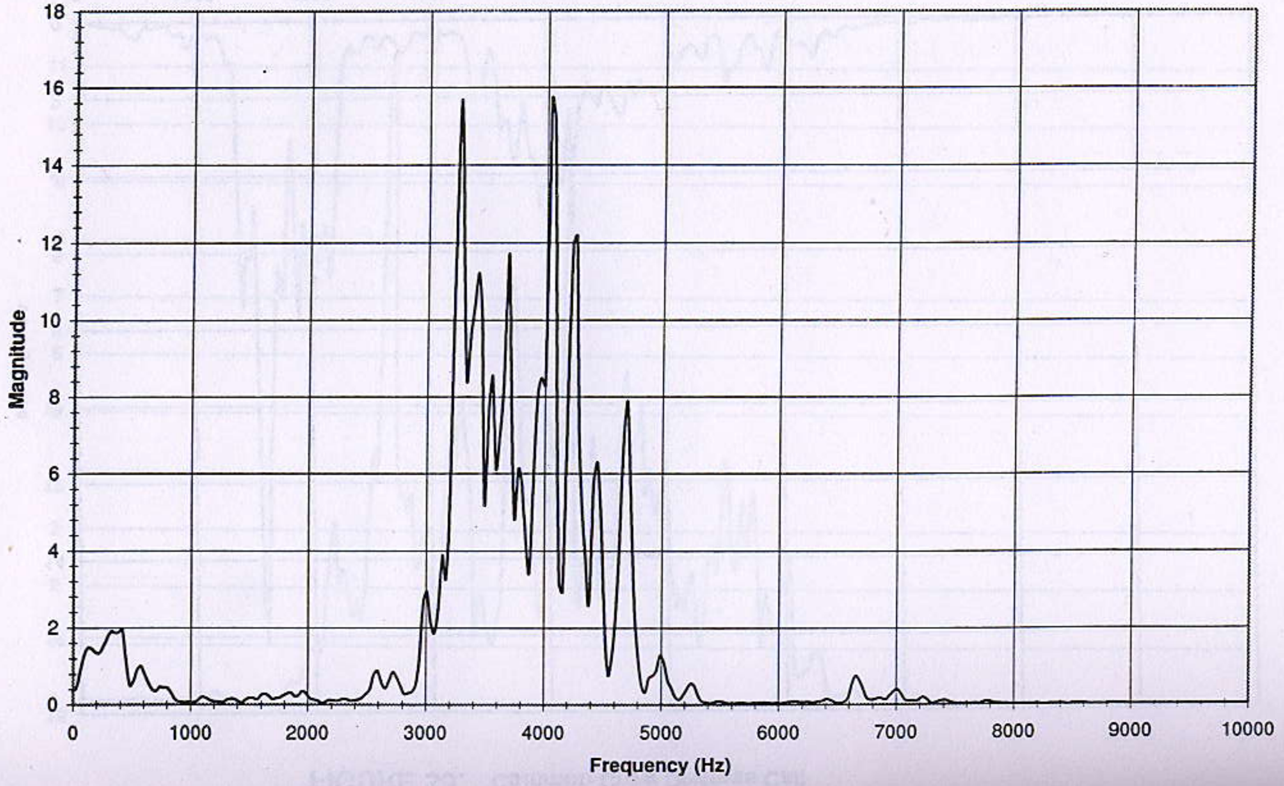
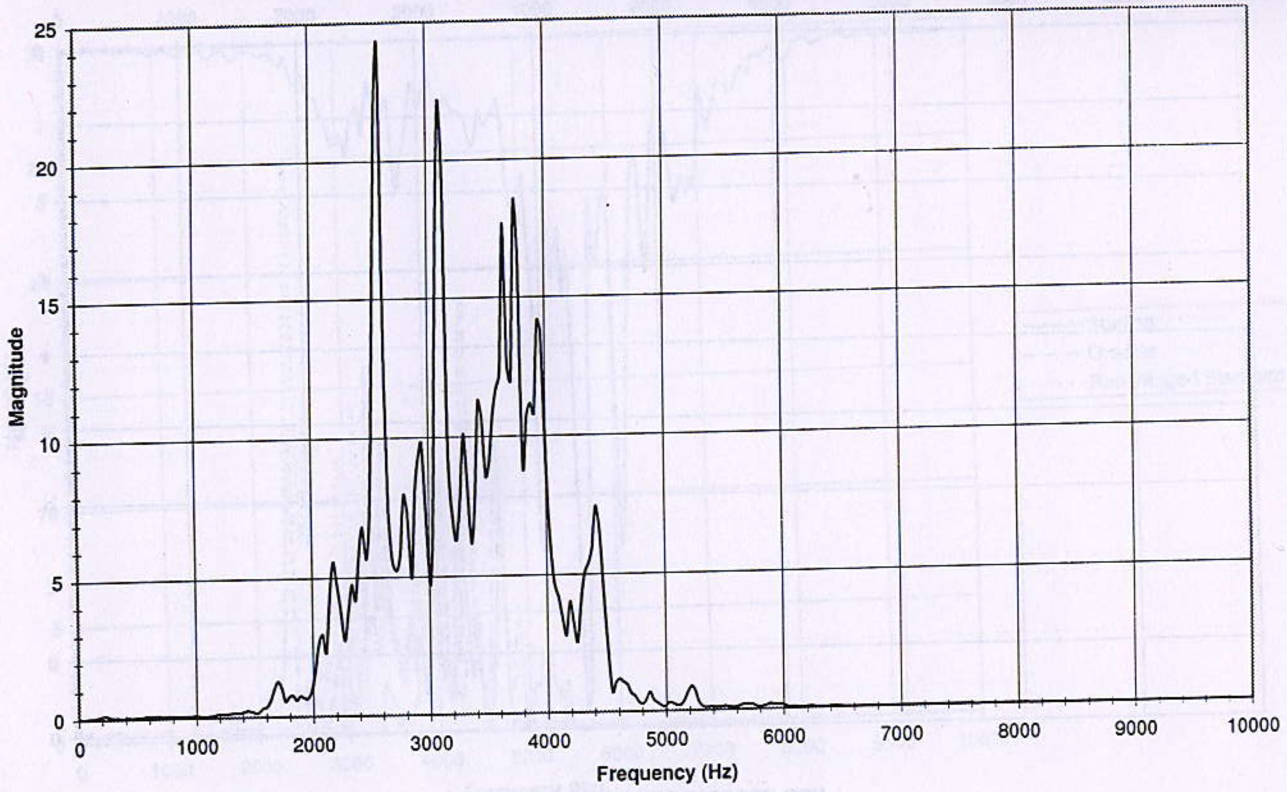
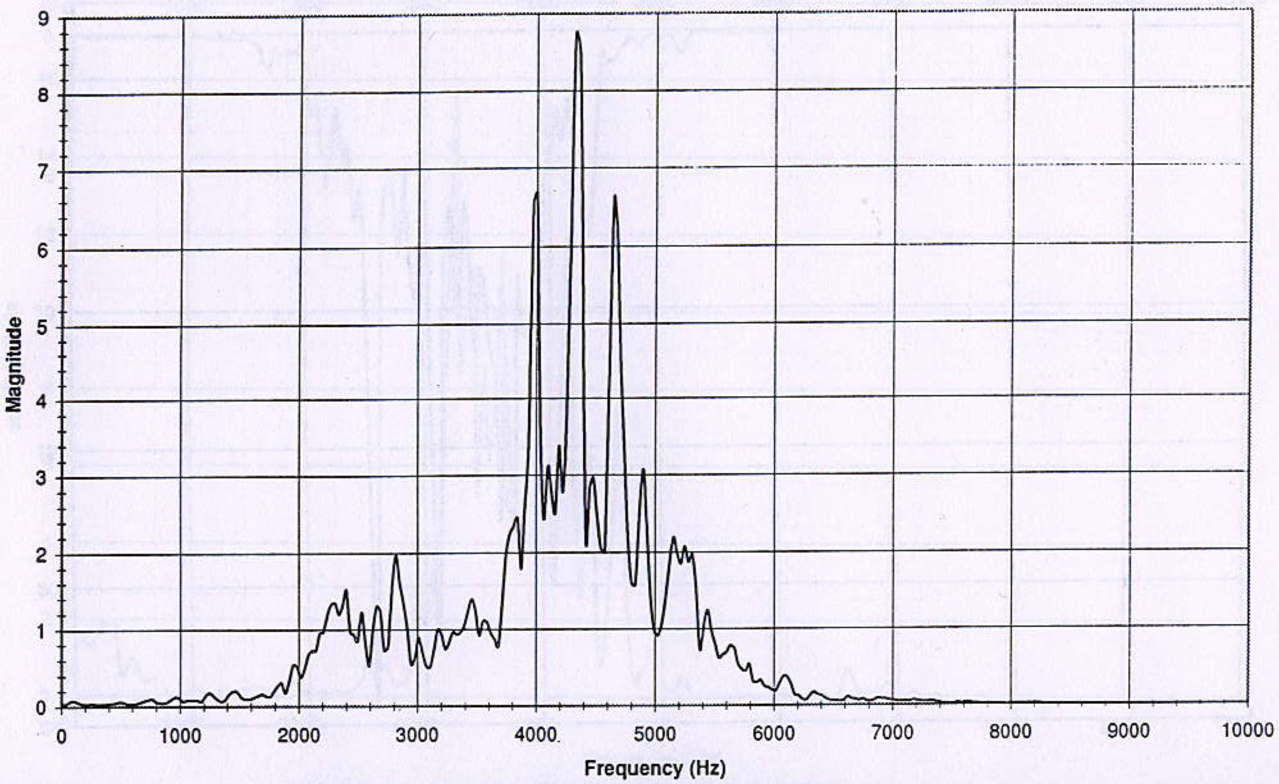


FIGURE 3f. Red-Winged Blackbird Distress Call

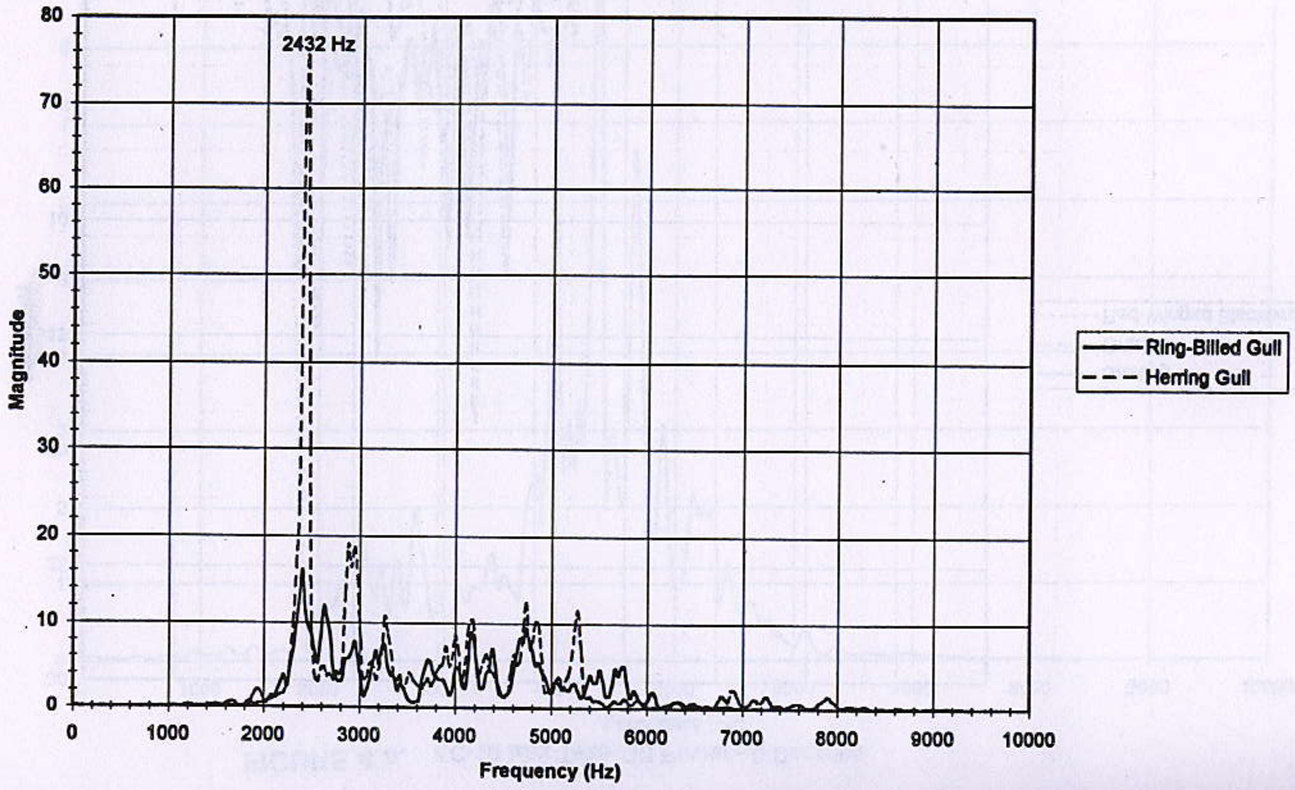




Common Grackle Distress Call

Cross Spectrum

FIGURE 4 b. KC-10 Max Take-Off Power - 0 Degrees



Cross Spectrum

FIGURE 5 a. **KC-10 Max Take-Off Power - 10 Degrees**

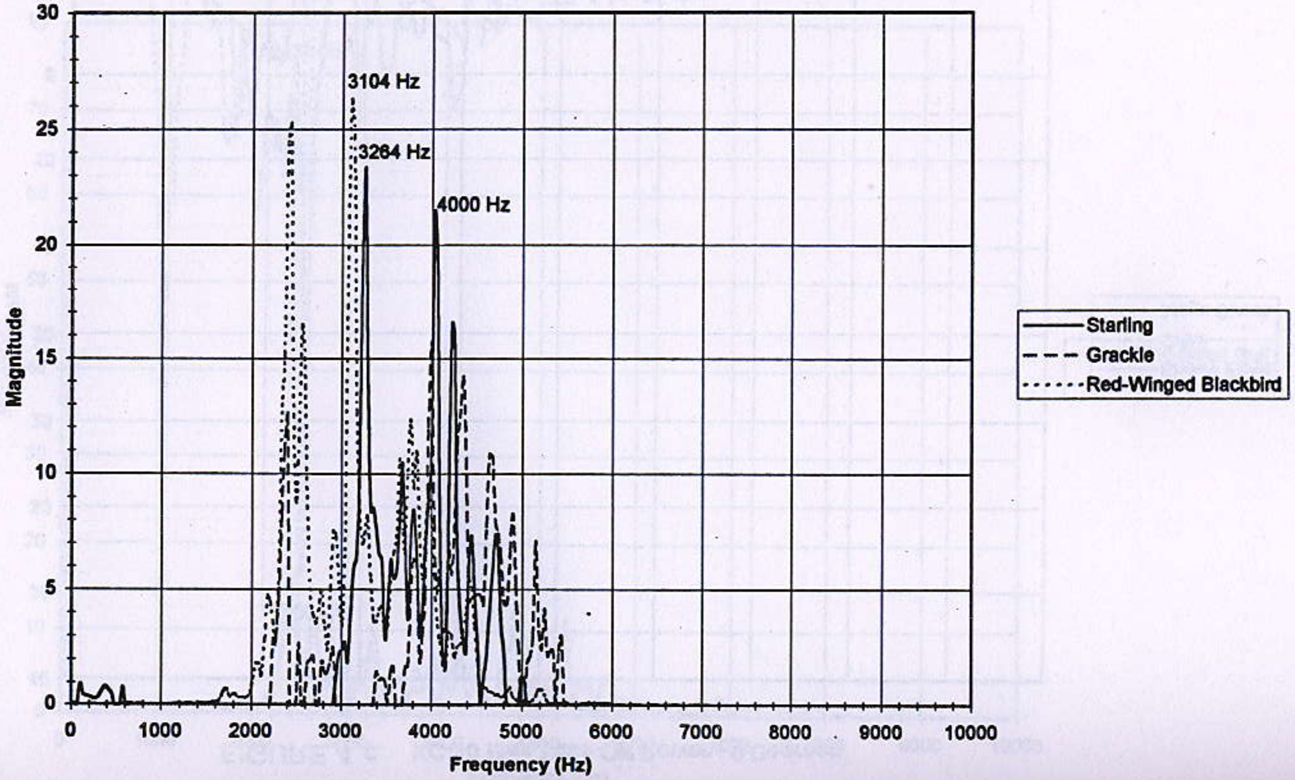


FIGURE 5 b. **KC-10 Max Take-Off Power - 10 Degrees**

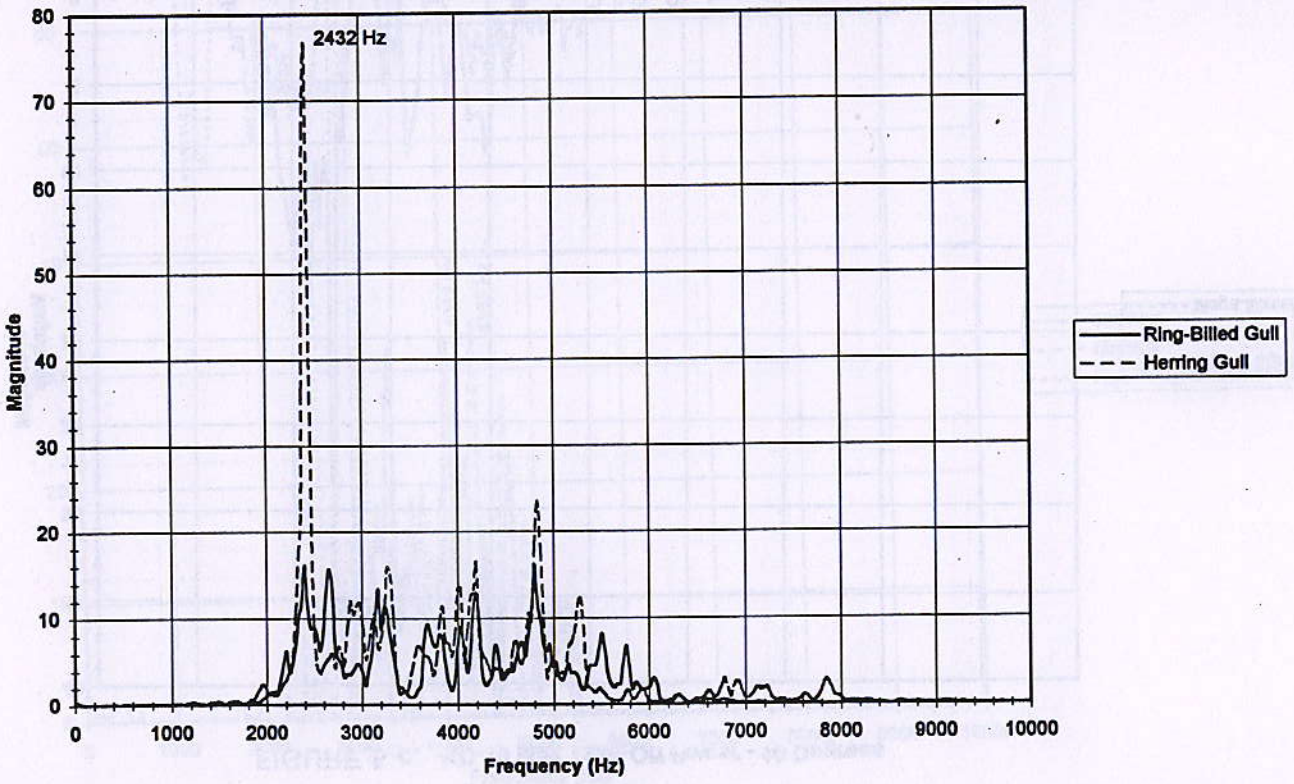
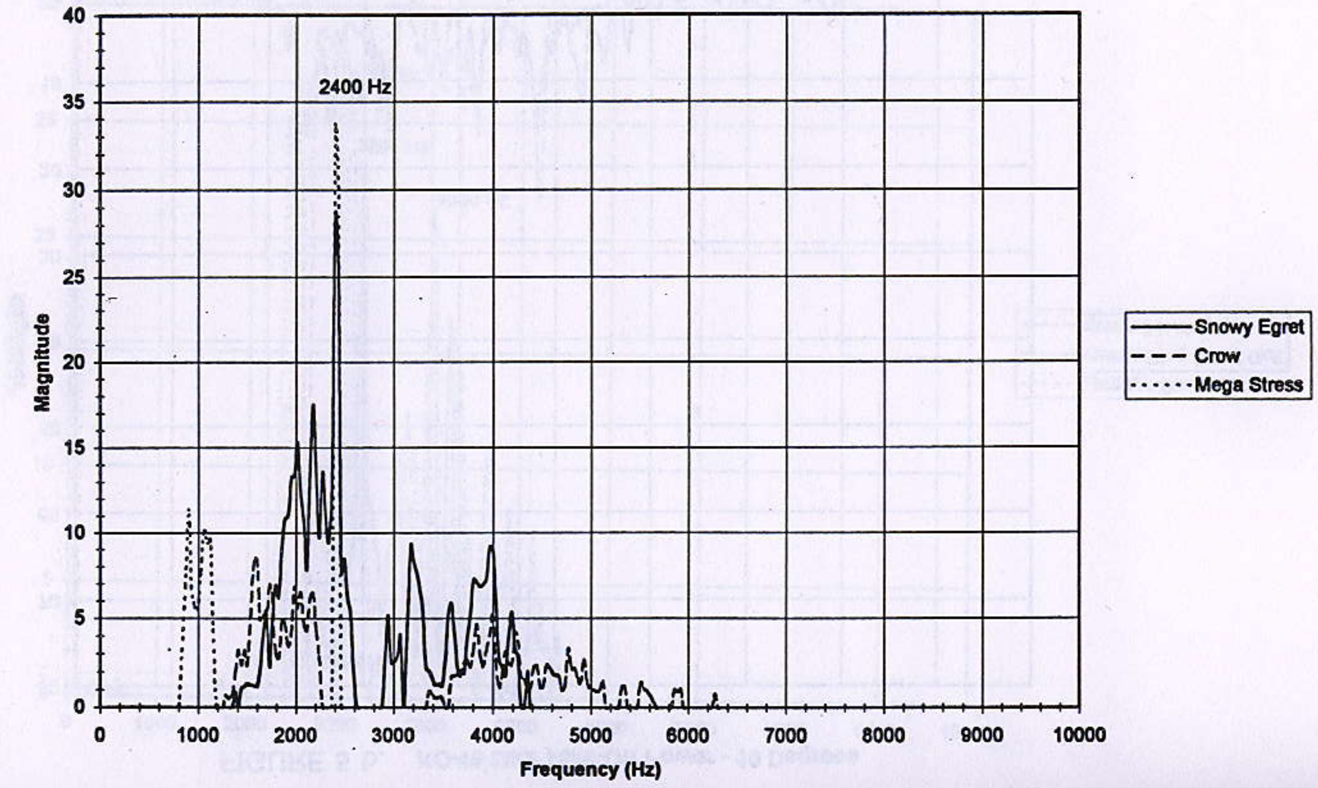
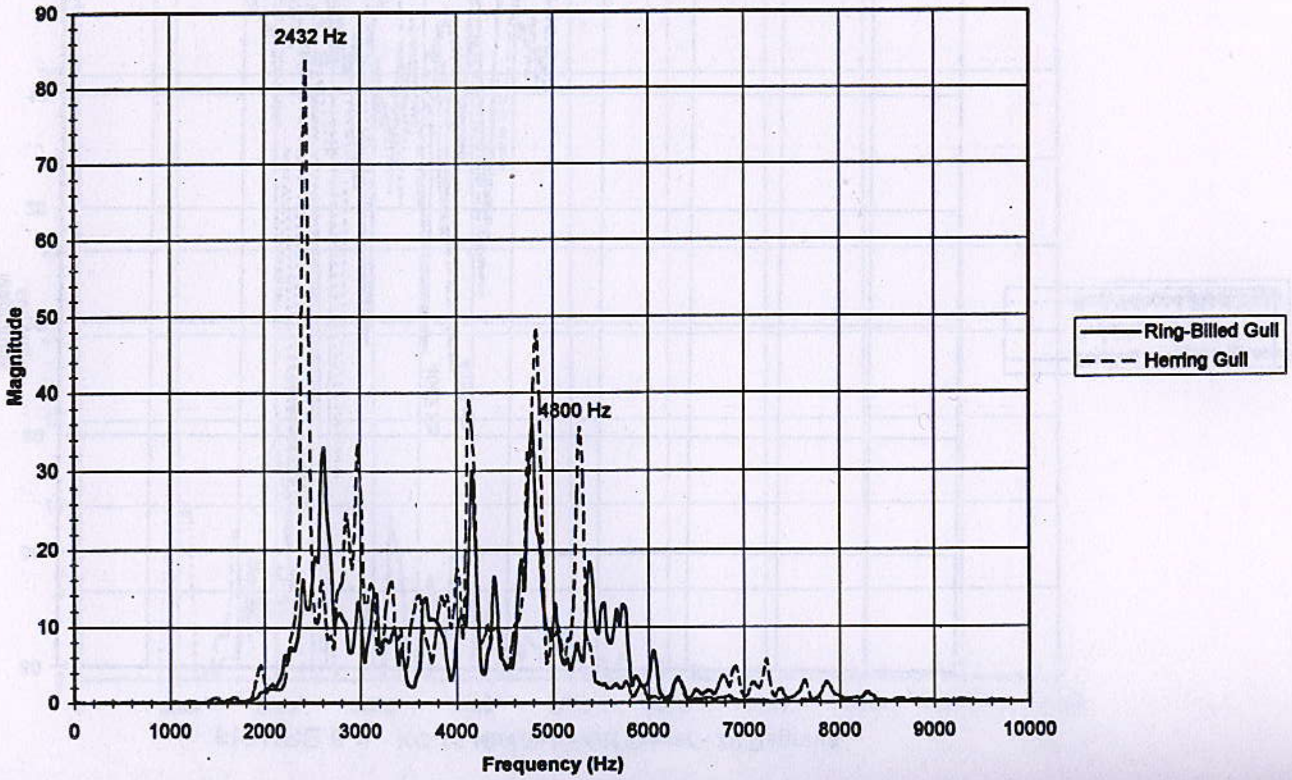


FIGURE 5 c. KC-10 Max Take-Off Power - 10 Degrees



Cross Spectrum

FIGURE 6 b. KC-10 Max Take-Off Power - 20 Degrees



Cross Spectrum

FIGURE 6 c. **KC-10 Max Take-Off Power - 20 Degrees**