BIRD FEATHERS AS DIELECTRIC RECEPTORS OF RF FIELDS

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Summary

The characteristics of bird feathers as dielectric aerials have been investigated in the X-band region of the microwave spectrum.

Preliminary findings show that feathers may act as microwave sensors. Hence, man can influence the behaviour of birds by means of a microwave beam.

Introduction

Feathers play a fundamental role in the life, behavior, and survival of birds. Their functions are many and their interaction with the environment is far from being well understood. From the navigational standpoint, the role of feathers cannot be sufficiently overstressed. Thus, any interaction with external agents is likely to produce disturbances in the flying patterns and behavior of birds. From the electromagnetic point of view feathers can interact with the environment in a number of ways, their role being both of the passive and of the active type. In the first case they can be considered to act as selective filters and as transmission lines, their role being purely informational, carrying information from the environment to the bird and vice versa. In the second case, feathers can be considered to be energy transducers (direct physical interaction inducing biological effects). In this case information is also conveyed into and out of the system , though at a different level of complexity.

Investigation on feathers began in our laboratory some time ago with the study of their converse piezoelectric properties in the audiofrequency region[1,2,3]. This investigation was conducted in order to study the piezoelectric effects induced in feathers by pulsed microwave beams. The production of microwave acoustical phonons was also considered in detail. In addition, predictions on theoretical grounds[4] and strong experimental evidence[5] as to the role of feathers in the behavior of birds exposed to microwave radiation indicated the possibility that they may act as selective sensors of the surrounding medium. In view of these facts the characteristics of bird feathers as dielectric aerials were investigated in the X-band region of the microwave spectrum.

Experimental Apparatus

Experiments were conducted at a frequency of approximately 10 Ghz with the calamus of bird feathers. The specimens used had the following physical dimensions (in terms of the operating free-space wavelength λ_0): Length (L) = 4.5 λ_0, Diameter (D) = 0.3 λ_0, Thickness (t) = 0.02 λ_0. Radiation-patterns were recorded using the feather as receiving aerial. The radiation-pattern measuring apparatus is shown in FIG. 1. The radiator consisted basically of a standard horn antenna powered by a 0.5 Watt klystron tube. The microwave signal was attenuated by means of a 20 dB calibrated attenuator and matched to free-space by a slide screw tuner. A 20 dB cross-guide directional coupler provided the means for power and frequency monitoring. Internal modulation of the microwave signal was provided by a 1 kHz square wave. The receiving system (FIGS. 2 and 3) essentially consisted of a length of X-band rectangular waveguide. The waveguide acted as a primary transducer to which the calamus of the feather was directly coupled by a tight fitting elliptical aperture. Several feather-to-waveguide coupling combinations were investigated, two of which are reported here. In one case the elliptical aperture was located in the closed end of the waveguide (FIG. 2). In the second case the aperture was located on the narrow side of the waveguide (FIG. 3). One side of the waveguide was attached to a calibrated square-law detector. Matching between the receiving aerial and the crystal detector was accomplished by means of a slide screw tuner. The receiving system was clamped to a plexiglas stand positioned on a wooden turntable arranged with a scale (in degrees) that could be read at a distance (FIGS. 2 and 3). Both radiating horn and receiving system were located in an anechoid chamber (Eccosorb cell). The signal recorder at the crystal detector was amplified, filtered and displayed on the screen of an oscilloscope.

Radiation pattern measurements were conducted with and without the feather in place. In each case the receiving system was tuned for maximum power. In addition experiments were performed with a single feather and with an array of three feathers approximately $\lambda_g/2$ distant from each other (λ_g is the waveguide wavelength).

Results

FIGS. 4 (waveguide end coupling), 5, and 6 (coupling on the narrow side of waveguide) demonstrate that a substantial increase in the power received in the forward direction and a decrease in the beamwidth occurs when the feather is in place. As expected the increase in the forward gain is larger for the feather array than for the single feather. These two effects are probably due to a combined guiding and focussing effect on the microwave field by the feather. Some asymmetries exhibited by the radiation patterns are partly accounted for by the non-perfect aligment of the probe relative to the radiating horn, and by the irregular geometry of the feather, and the feather and microwave components.

Conclusion

If a similar effect as that described above takes place when the bird is in flight (or at rest), an increase in the microwave field strength should be "sensed" by the bird. The sensory mechanism is not yet fully understood, though it should involve the feather as a receptor of the incoming signal. Theoretical considerations[4], and experimental evidence[5] of this may be found in previous work. More experimental work in this direction is being conducted, concentrating on the effect of feather arrays on microwave fields. In addition, different types of feather couplings to the primary transducer are under investigation[6,7]. Experiments are also in progress at lower and higher frequencies.

So far, we have investigated two new properties of bird feathers. They exhibit converse piezoelectric properties in the audiofrequency region[1,2,3], and they act as microwave dielectric aerials[6,7]. Recently, experiments performed in our laboratory with feathers show the production of converse piezoelectric effects by pulsed microwave beams. In addition, the converse piezoelectric properties of bird feather has been extended beyond the audiofrequency region[8].

The results obtained so far are highly encouraging in relating the effects of microwave radiation to the behavior of birds in the presence of microwave sources.

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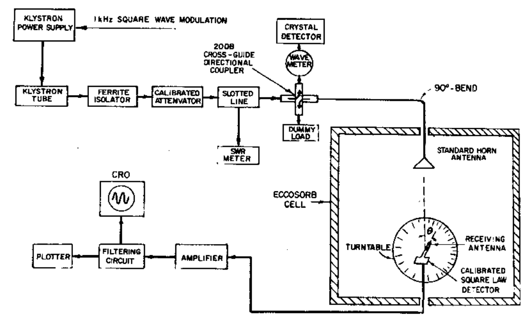


FIG. I EXPERIMENTAL SET-UP FOR RADIATION PATTERN MEASUREMENTS

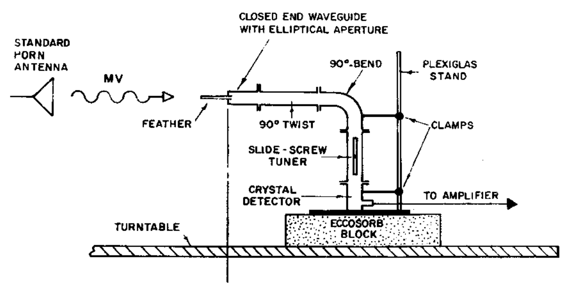


FIG.2 DIRECT FEATHER TO WAVEGUIDE COUPLING ARRANGEMENT

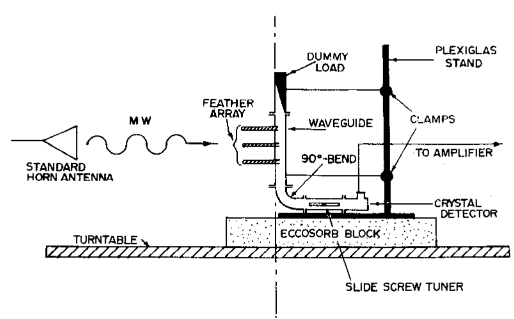
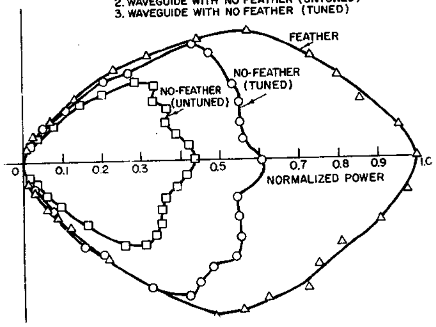


FIG. 3 DIRECT FEATHER (SINGLE OR ARRAY) TO WAVE-GUIDE COUPLING

FIG. 4 EXPERIMENTAL RADIATION PATTERNS FOR
1. FEATHER & WAVEGUIDE (TUNED)
2. WAVEGUIDE WITH NO FEATHER (UNTUNED)
3. WAVEGUIDE WITH NO FEATHER (TUNED)



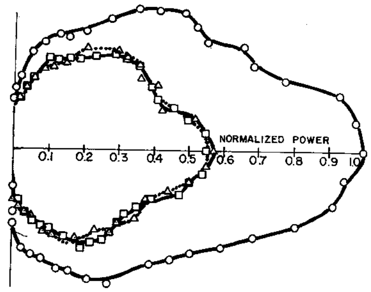


FIG. 5 EXPERIMENTAL RADIATION PATTERNS FOR
O—O FEATHER AND WAVEGUIDE (TUNED)
□—□ WAVEGUIDE WITH NO FEATHER (UNTUNED)
△······△ WAVEGUIDE WITH NO FEATHER (TUNED)

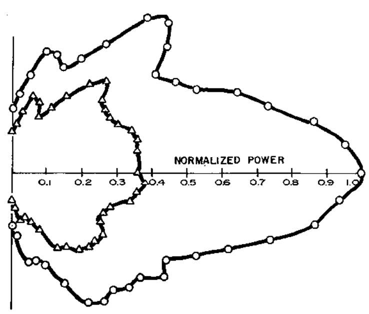


FIG. 6 EXPERIMENTAL RADIATION PATTERNS FOR
O—O FEATHER ARRAY AND WAVEGUIDE (TUNED)
△—△ WAVEGUIDE WITH NO FEATHERS (TUNED)