Tracking very-low-power ground transmitters from near earth orbit

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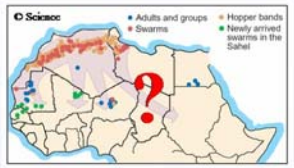
Bird and bat migration

Human health

Locust swarms



A Global Problem

- Many biological and technical processes involve long-distance (cross-continental) dispersal/migration of small propagules

- Smallest PPT tags are 18 grams, thus the smallest animal tracked globally is ~400 grams

- Most ecologically and economically important species are smaller than 400 grams, such as bats, birds, insects

- Biologists need a system to track disease transmission (West Nile virus), migration routes (conservation), and pests (locust plagues)

Why a new animal-tracking satellite when such satellites already exist and have had considerable success?

Existing systems require relatively massive and bulky transmitters on the animal. A small passerine bird can carry a payload which is only a small fraction of its body mass, say 3%, without seriously inhibiting its behavior. Currently, transmitter modules are available which weigh one gram or less, including antenna and battery, which deliver peak pulse power of one milliwatt, and which can emit 20 millisecond pulses at one second intervals for durations of one month or more. Such a transmitter is inadequate for tracking by existing satellite systems.

Signal strength requirements for detection of a single, short pulse from a low orbit satellite.

Assumptions

- Receiver system noise temperature 50 Kelvin.
- Satellite height 400 Km.
- Earth is a black body at 300 K, completely occulted by the antenna beam.
- Receiver bandwidth B = 10 KHz. Limits noise power and data rate. Precludes pulse length < 0.1 millisecond.
- Earth (animal) antenna is isotropic, gain 0 dB; efficiency 10%.
- Satellite receiving antenna gain 15 dBi At 150 MHz the effective area is 10 M2.
- Required signal to noise power ratio at detector 10 dB.
- Boltzmann's constant k = 1.38 x 10-23 Watt/K/Hz.

Required Ground Transmitter Power:
1milliwatt

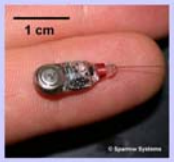


Figure 1. Example of a transmitter that is currently used in bird research that could be tracked from a low-orbit satellite

Results - Solution

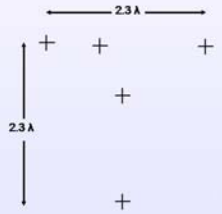


Figure 2 Geometrical locations of antennas in an array 2.3 x 2.3 wavelengths in extent

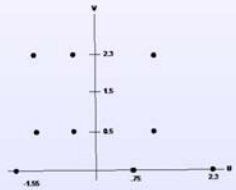


Figure 3 Sampling points in the spatial frequency spectrum of the antenna array.
U and V scale is units D/λ.

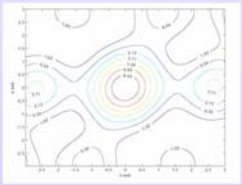


Figure 4. Response of the above array to a point source in the far field. X and Y axes scaled in radians.

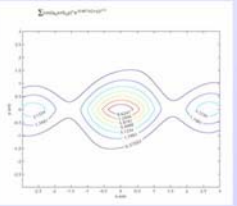


Figure 5. Response of the above array to a point source when synthesized map is multiplied by the primary antenna beam. X and Y axes scaled in radians.

Scientific Impact

The increase in biological knowledge will be enormous and immediate. Several tracking seasons will provide biologists with data that can be analyzed for decades.

Figure 6. Globally, the single best data set on songbird migration is one 6-day track of a Swainson's thrush through the Midwestern USA. Cochran, W. W. (1987). "Orientation and other migratory behaviors of a Swainson thrush followed for 1500-km." Animal Behaviour 35: 927-929.