inhibition" advanced by the Hellströms and the Möllers (*16*). According to this view, based on complex in vitro and transplant experiments, cells of different histocompatibility types can destroy or inhibit each other on direct contact, without antibody formation or immune-system intervention, and can thereby act as a surveillance system in the organism by eliminating variant cells. While the observations are of interest, they appear to be strictly *sui generis* and to apply to the unusual conditions of those experiments rather than to the biological situation more characteristic of an organism. From allophenic mice, it is clear that in an intact, unirradiated, and healthy animal, cells of diverse histocompatibility types can coexist in any tissue for an entire lifetime with complete impunity.

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Radio Reflection by Free Radicals in Earth's Atmosphere

Barry, Coleman, Libby, and Libby (*1*) suggest that signals recorded by the Canadian satellite Alouette II are due to the stimulated emission of magnetic-dipole radiation from Zeeman transitions of free radicals in the earth's magnetic field. The main evidence presented in favor of this hypothesis is that the signals appear to track with the value of the magnetic field at the satellite and that the observed frequencies give Landé g values (proportional to the ratio of signal frequency to local magnetic field) between 0.6 and 1.8, which are in the same range as some known ground- or metastable-state g values of free radicals. The ionograms shown were taken over the Antarctic with the satellite at altitudes of 1000 to 1300 km where the earth's field is about 0.3 gauss. It was tacitly assumed that the radiation propagates at the free-space velocity, and the same assumption is used in most of the following.

Unfortunately, the calculation given in (*1*) for the signal due to induced magnetic dipole transitions is incorrect. The authors assume that the energy lost by those free radicals which were initially in an upper Zeeman sublevel is radiated isotropically, that those in the lowest sublevel do not take part in the radiation process, and that the amplitudes back at the satellite antenna add incoherently. Actually, only spontaneous emission together with the difference between the stimulated emission and the absorption play a role. Also, any excess stimulated emission energy will travel away from the satellite, in the same direction as the transmitted pulse, owing to a net constructive interference between the electromagnetic wavelets radiated by the free radicals and the very much stronger stimulating wave (*2*).

We can find the power radiated back to the satellite by quantum mechanical calculation of the expectation value of the oscillating magnetic dipole moment, and by then putting this value into the standard magnetic dipole radiation formula derived from Maxwell's equations. For completely incoherent addition of the radiation from each free radical as assumed in (*1*), the actual power returned to the antenna would be weaker by a factor of about 10^{20} than that calculated in (*1*) and would just correspond to normal spontaneous emission. This is in agreement with the standard result obtained if the radiation field is quantized also: namely that the stimulated emission due to a given mode of the radiation field goes into the same mode provided that coupling between the modes can be neglected.

To calculate the actual power that would be returned to the Alouette II satellite, still assuming free-space propagation, we must take account of the relative phases of the wavelets radiated by the free radicals. We assume a satellite dipole antenna along the the earth's field direction and take this to be the axis. For resonance at $\nu = 10^6$ cy/sec, $J = \frac{1}{2}$, and $g = 2$ and for distances of roughly a wavelength or greater from the satellite, the oscillating magnetization per unit volume in the azimuthal direction is given approximately by

$$M = 4.5 \times 10^{-14}\left(\frac{\sin\theta}{r}\right) \times$$
$$\tau(N_+ - N_-)\, e^{ikr}e^{-i\omega t} \quad [\text{erg gauss}^{-1}\ (\text{cm}^3)^{-1}]$$

Here r is the distance from the antenna, θ is the angle between r and the axis, $k = 2\pi/\lambda$, λ is the wavelength, $\omega = 2\pi\nu$, $\tau \leq 10^{-4}$ second is the time the satellite pulse has been on at the point in question, and $N_+ - N_-$ is the difference between the number of radicals per cubic centimeter initially in the upper and the lower Zeeman sublevels. After adding up the contributions to the electric field along the satellite antenna which were due to the magnetization in each element of volume and estimating the contributions from closer than a wavelength to the antenna, we find that a value of $N_+ - N_-$ of about 10^7/cm would be needed in order to give observable signals. The contributions from the near-field and far-field regions are comparable. The power returned to the satellite should be regarded as enhanced spontaneous emission from a highly radiating state set up by the satellite pulse.

From the above result and the normally assumed total atmospheric density of $N < 10^6/\text{cm}^3$ at the altitudes of interest, it seems highly unlikely that the Alouette II signals discussed (*1*) are due to induced magnetic dipole radiation from free radicals. If the radicals had a thermal equilibrium distribution over the Zeeman levels, a density of about $10^{14}/\text{cm}^3$ would be required for observable signals, since $(h\nu/kT) \sim 10^{-7}$. This agrees with the estimates made by Hodges and Colegrove (*3*) in refuting an earlier proposal for finding the density of free radicals at altitudes near 300 km by rocket measurements of enhanced electromagnetic radiation intensities near magnetic resonance frequencies.

Optical pumping can, in suitable cases, increase the population difference between ground-state sublevels (*4*). However, for enhanced Zeeman frequency emission between nearly equally spaced sublevels, an enhanced initial polarization of the system is necessary. This would normally require pumping by partially circularly polarized light. The assumption of very special population difference and field inhomogeniety distributions in order to cancel out the e^{ikr} phase factor in the magnetization and the similar one in the propagation back to the satellite would be unreasonable, and even leaving out the phase factors completely could not reduce the required value of $N_+ - N_-$ by more than a factor of 1000.

We now consider the effect of the transmitter frequency being considerably below both the plasma and the electron cyclotron-resonance frequencies for the medium. For a cold, collisionless plasma in a magnetic field, one mode can always propagate in directions which are not too close to perpendicular to the field. However, exponential damping rather than propagation will take place for this mode for directions nearly perpendicular to the field, and for the other mode at low enough frequencies. As an extreme model of local trapping of the energy, we will assume that all of the energy normally emitted during one satellite pulse is stored for 10^{-4} second in a region roughly a free-space wavelength in diameter. This would give nearly the maximum possible precessing magnetization per unit volume for this region. If the electric field at the antenna is calculated by the free-space formulas, the required value of $N_+ - N_-$ is still greater than $10^6/cm^3$. The calculated satellite signal appears to depend only weakly on the distribution in space of the oscillating magnetic field energy.

It should be emphasized that the difficulty of observing magnetic dipole transitions in the earth's field is due to the extremely small size of the Bohr magneton. For a single free radical initially in an upper Zeeman sublevel, the power radiated back to the satellite after a resonant 10^{-4}-second pulse at 1 mc/sec is roughly a factor of 10^{24} weaker than for a free electron. In order for such a free radical to lose half its initial energy by nearly isotropic radiation in 10^{-4} second, it would have to radiate at the same average rate as a classical precessing magnetic moment of about 10^{14} Bohr magnetons.

In view of the foregoing conclusions, it does not seem worthwhile to comment on the particular free radicals suggested by Barry *et al.* (*1*) as possible contributors to the Alouette II signals. The suggestion made earlier (*5*) and repeated by Barry *et al.* (*1*), that free radicals in Jupiter's atmosphere may "transduce" Alfvén-wave energy into the observed decameter radio emission, also seems highly unlikely in view of the strong tendency for enhanced spontaneous emission from large regions, after a stimulating pulse, to go in the forward direction, like radiation produced by induced emission.

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The general arguments (*1*) against our theoretical treatment (*2*) of the reflected radio signals found by the Canadian satellite Alouette II have been well known to us from the beginning. It was in the face of them that we advanced our simple theory of isotropically induced emission in the belief that the true conditions of the high atmosphere justified this approach.

The variation in magnetic field causes the resonant frequency, which is extremely narrow because of the long spontaneous-emission lifetime, to vary by several parts per million in one wavelength, and the thermal Doppler broadening also amounts to several parts per million. This means, because of these two effects, that few dipoles have matching frequencies, and coherence is improbable.

Effectively we are reducing each dipole to its own narrow frequency, with relatively few photons of that frequency incident, so that Bose statistics do not command forward emission (*3*). For these reasons we take the view that each dipole acts independently, and that isotropically induced emission is not unreasonable.

We continue to find reflections at the frequencies expected (particularly O^+ in its various electronic states) and at about the intensities calculated from the concentrations indicated by other evidence (*4*), by use of our simple treatment. In particular, frequent reflections are observed in middle latitudes.

It is possible that we have misinterpreted the entire phenomenon, but we believe that the present evidence is convincing; we continue the research, looking particularly for latitude and diurnal effects.

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