Production of EM Surface Waves by Superconducting Spheres: A New Type of Harmonic Oscillators

A. Meessen
Institute of Physics, Catholic University of Louvain, Louvain-la-Neuve 1348, Belgium

Abstract— It is shown that a superconducting sphere or spherical shell can produce EM surface waves that are stationary at *any* low frequency. This applies in particular to *magnetic dipole oscillations*, generated by a current density **J** that oscilllates around a given axis on the surface of the sphere. In the quasistatic approximation, it creates a synchronously oscillating magnetic field **B**, while the resulting electric field **E** provides feedback to sustain the current. This yields a new type of oscillators, where the magnetic energy is not completely transformed into electric energy as in classical LC circuits. EM energy is conserved, however, by means of energy fluxes. The purpose of this theory is to account for *evidence of very intense magnetic dipole fields*, produced by unconventional flying objects of unknown origin. These observations would make sense and suggest that superconductivity is possible at normal atmospheric temperatures. We also examine the propagation of plasma waves along superconducting surfaces and consider possible pairing mechanisms.

1. INTRODUCTION

This research was motivated by the fact that the propulsion system of "Unconventional Flying Objects" (UFOs) can be explained when we assume that they are able to produce very intense dipolar magnetic fields, oscillating at low frequencies [1]. We want thus to find out how these fields could be produced and if they have a finite range as well as other special properties. There is also an intrinsic, physical reason. Indeed, EM waves were initially produced as "surface waves", since Heinrich Hertz tried to verify the validity of Maxwell's theory by coupling *a long metal wire* to an LC circuit [2, 3]. The HF oscillating current, surrounded by oscillating electric and magnetic fields, was reflected at the end of the wire. This should produce a standing wave pattern and allow for an indirect measurement of the velocity c, but the EM surface wave was also reflected by laboratory walls. This perturbed the experiment so much, that Hertz prefered to use an oscillating electric dipole, emitting freely propagated EM waves. Since Lecher found that *two parallel wires* produce much more concentrated EM surface waves, he could realize the initially projected measurement [4]. Considerable effort was then devoted to the theoretical understanding of wave guides, formed by a single wire [5] and two parallel wires of finite conductivity [6].

Zenneck [7] considered the propagation of EM surface waves along *an infinite plane surface*, separating air from a material of given conductivity σ and dielectric constant ε. This problem was also treated by other authors [8–10]. EM surface waves were then considered for thin metal films, to account for characteristic electron energy losses [11] and optical resonance absorption [12]. These effects result from the creation of surface plasmons. Here, we consider stationary EM surface waves for a superconducting sphere and EM waves that propagate along a superconducting plane. Since UFOs are topologically equivalent to a sphere, we will adopt this model to concentrate on essential features. The nature of the surface material is unknown, but it is sufficient that it contains a high density of electron pairs to be a superconductor, obeying known physical laws. To evaluate the intrinsic properties of this system, we assume here that the outside medium contains no free charges.

2. BASIC EQUATIONS

The *quasistatic approximation* is valid for electric fields **E** and magnetic fields **B** that oscillate at extra-low frequencies (ELF) in a portion of space that is small compared to the corresponding wavelength. Retardation effects can then be neglected, as if c were infinite. For nonmagnetic and electrically neutral media, Maxwell's equations are thus reduced to

$$\nabla \times \mathbf{B} = \mu_o \mathbf{J} \quad \text{and} \quad \nabla \cdot \mathbf{B} = 0 \tag{1}$$

$$\nabla \times \mathbf{E} = -\partial_t \mathbf{B} \quad \text{and} \quad \nabla \cdot \mathbf{E} = 0 \tag{2}$$

$\mathbf{J}$ is the current density, acting as a source. We can also use the vector potential $\mathbf{A}$, since

$$\mathbf{B} = \boldsymbol{\nabla} \times \mathbf{A} \quad \text{and} \quad \mathbf{E} = -\partial_t \mathbf{A} \tag{3}$$
$$\Delta \mathbf{A} = -\mu_o \mathbf{J} \quad \text{and} \quad \boldsymbol{\nabla} \cdot \mathbf{A} = 0 \tag{4}$$

We will solve these equations *inside and outside a superconducting sphere* or spherical shell of radius R. The outside medium is unionized air, where the current density $\mathbf{J} = 0$, but the superconducting material contains *free electron pairs* (of mass $2\,m$ and charge $-2e$). Being bosons, they remain in their ground state of momentum $\mathbf{p} = 2(m\mathbf{v} - e\mathbf{A}) = 0$. When n is the density of electrons in the superconducting state, the current density $\mathbf{J} = -en\mathbf{v}$, since there are $n/2$ electron pairs of charge $2e$. Thus,

$$\mu_o \mathbf{J} = -\alpha^2 \mathbf{A} \quad \text{where} \quad \alpha^2 = \mu_o n e^2/m = \mu_o s \tag{5}$$

Combining (5) with (4), we get two equations for $\mathbf{A}$ alone:

$$\Delta \mathbf{A} = \alpha^2 \mathbf{A} \quad \text{with} \quad \boldsymbol{\nabla} \cdot \mathbf{A} = 0 \tag{6}$$

They are valid outside and inside the sphere, where α is either zero or very great. This parameter is essential for the current density $\mathbf{J}$, which is not only the source of $\mathbf{E}$ and $\mathbf{B}$, but depends also itself on these fields. However, Ohm's law is not valid anymore inside a superconductor. It has to be replaced by *the London equations*

$$\partial_t \mathbf{J} = s\mathbf{E} \quad \text{and} \quad \nabla \times \mathbf{J} = -s\mathbf{B} \tag{7}$$

Since electron pairs cannot leave the state $\mathbf{p} = 0$, their equation of motion would be $2m\partial_t \mathbf{v} = -2e\mathbf{E}$ when $\mathbf{B} = 0$. The second Equation (7) accounts for the Meissner effect and the finite penetration depth of magnetic fields inside superconductors. We are actually considering *a macroscopic quantum state* with a rather stable wavefunction.

3. MAGNETIC DIPOLE OSCILLATION

Now, we solve Equation (6) to determine the vector potential $\mathbf{A}$ and the resulting fields $\mathbf{E}$ and $\mathbf{B}$ when the current density $\mathbf{J}$ is oscillating at frequency ω on the surface of the superconducting sphere around a given z-axis. Using spherical coordinates (r, θ, φ), we set

$$\mathbf{J} = (0, 0, J) \cos \omega t \quad \text{and} \quad \mathbf{A} = (0, 0, A) \cos \omega t \tag{8}$$

Because of (5), $\mu_o J = -\alpha^2 A$. The second Equation (6) requires that $A = A(r, \theta)$ and (3) yields

$$\mathbf{E} = \omega(0, 0, A) \sin \omega t \quad \text{and} \quad \mathbf{B} = (B_r, B_\theta, 0) \cos \omega t \tag{9}$$

with

$$rB_r = \frac{1}{\sin\theta} \partial_\theta (\sin\theta A) \quad \text{and} \quad rB_\theta = -\partial_r (rA) \tag{10}$$

At the poles, $J = A = 0$. The simplest solution of the first Equation (6) corresponds thus to

$$A = \frac{u(r)}{r} \sin\theta \quad \text{where} \quad u'' - \frac{2}{r^2} u = \alpha^2 u$$

Outside the sphere, $\alpha = 0$, so that $u(r)$ decreases like $1/r$ for increasing distances from the center of the sphere. Inside the sphere, we could use Bessel functions for $u(r)$, but it is sufficient to consider an exponential decrease towards the inside of the sphere (for $r \approx R$ and $\alpha R \gg 1$). Distinguishing solutions outside and inside the sphere by subscripts + (when $r > R$) and − (when $r < R$), we get

$$A^+ = \frac{M}{r^2} \sin\theta \quad \text{and} \quad A^- = \frac{M}{R\,r} e^{\alpha(r-R)} \sin\theta \tag{11}$$

This accounts for the continuity of the tangential component of $\mathbf{E}$, defined by (9). Because of (10), the components of the magnetic field $\mathbf{B}$ are

$$B_r = \frac{2u(r)}{r^2} \cos\theta \quad \text{and} \quad B_\theta = \frac{-u'(r)}{r} \sin\theta$$

Thus,

$$B_r^+ = \frac{2M}{r^3}\cos\theta \quad \text{while} \quad B_r^- = \frac{2M}{R\,r^2}e^{\alpha(r-R)}\cos\theta \tag{12}$$

$$B_\theta^+ = \frac{M}{r^3}\sin\theta \quad \text{while} \quad B_\theta^- = \frac{-\alpha M}{R\,r}e^{\alpha(r-R)}\sin\theta \tag{13}$$

Outside the sphere, we get *a perfect magnetic dipole field*, but inside the superconducting sphere, the fields $\mathbf{E}$ and $\mathbf{B}$ decrease very rapidly, since the penetration depth $1/\alpha$ is small compared to R. The radial component of $\mathbf{B}$ is continuous at the surface, but the tangential component is not. This requires *a surface current density* $\mathbf{J}_s = (0, 0, J_s)\cos\omega t$, where

$$\mu_o J_s = B_\theta^+ - B_\theta^- = \alpha\frac{M}{R^2}\sin\theta \qquad (\text{for } \alpha R \gg 1) \tag{14}$$

Inside the sphere, the volume current density (8) is also parallel to the surface, but has the opposite sign and for $r = R$, its magnitude is α times greater than (14). The quasi-infinite surface current density J_s accounts for the Meissner effect or perfect diamagnetism. We could also consider other multipole oscillations, but magnetic dipole oscillations are sufficient to become aware of remakable facts.

4. ENERGY CONSERVATION AT ANY LOW FREQUENCY

LC circuits are based on a complete conversion of magnetic energy into electric energy and vice-versa. These energies are respectively associated with the magnetic field $\mathbf{B}$ near the current carrying coil and the electric field $\mathbf{E}$ inside the charged condensor. However, there are no condensors that could prevent breakdown for extremely intense electric fields, while EM surface waves around a spherical superconductor yield *non segregated* electric and magnetic fields. Moreover, there is *no eigenfrequency* as for LC circuits. Any low frequency ω is possible and *it is not necessary to convert the whole magnetic energy into electric energy*, although we have to consider work done by the electric field $\mathbf{E}$. Since it acts on electron pairs inside the superconductor, the dissipated power per unit volume is

$$P = \mathbf{J}\cdot\mathbf{E} = JE\sin\omega t\cos\omega t$$

It varies like $\sin 2\omega t$, but (1) and (2) lead to *a special form of Poynting's theorem* in the quasistatic approximation:

$$P = -\boldsymbol{\nabla}\cdot\mathbf{S} - \partial_t U \quad \text{where} \quad \mathbf{S} = (\mathbf{E}\times\mathbf{B})/\mu_o \quad \text{and} \quad U = B^2/2\mu_o$$

$\mathbf{S}$ defines the energy flux, which varies also like $\sin 2\omega t$. The magnetic energy density U varies like $\cos^2\omega t$, but its time derivative is proportional to $\sin 2\omega t$. For radiation in free space, we would have to consider also the electric energy $\varepsilon_o E^2/2$, where $\varepsilon_o = 1/\mu_0 c^2$, which is negligible when c is quasi-infinite and there are no static charges. With the previous notations, energy conservation would thus require that

$$\mu_o JE = -\frac{1}{r^2}\partial_r(r^2 EB_\theta) + \frac{1}{r\sin\theta}\partial_\theta(\sin\theta EB_\theta) - \omega(B_r^2 + B_\theta^2)$$

Setting $J = j(r)\sin\theta$, $B_r = F(r)\cos\theta$, $B_r = G(r)\sin\theta$ and $E = H(r)\cos\theta$, where j, F, G and H are defined by (8), (9), (11), (12), (13) and (14), the energy conservation would be insured if

$$\mu_o jH = -\frac{1}{r^2}\partial_r(r^2 HG) + \frac{3}{r}HF + \omega(F^2 - G^2) \quad \text{and} \quad \frac{2}{r}HF = \omega F^2$$

This is easily verified outside the superconductor, where $j = 0$, but is also true inside the superconductor, where all these functions are exponentially decreasing towards the center of the sphere, with $\alpha R \gg 1$. To account for the surface current density $\mathbf{J}_s$ we enclose an element of unit surface at the interface between two infinitely close parallel surfaces. Inside this layer, the dissipated power is $P_s = J_s E$, while the magnetic energy is zero. However, the energy flux $\mathbf{S}$ has a discontinuous radial component:

$$S_r^\pm = -\frac{1}{\mu_o}EB_\theta^\pm \quad \text{so that} \quad J_s E = -(S_r^+ - S_r^-)$$

This is equivalent to the definition (14) of J_s. The total energy is *always and everywhere* perfectly conserved, but not only because of the absence of resistive and radiative energy losses. It is also due to the quasistatic approximation, allowing for energy fluxes.

5. PROPAGATION OF SURFACE PLASMA WAVES

For a more complete exploration of this matter, we consider also EM waves that are propagating along the surface of a superconductor. Even a small portion of a large spherical surface can be treated like a plane, when the wavelength is small compared to the radius of this sphere. Using Cartesian coordinates, where the x-axis is normal to this surface, situated at $x = 0$, we consider an EM wave that propagates along the y-axis:

$$\mathbf{A} = (A_x, A_x, 0)e^{i(ky-\omega t)} \quad \text{and} \quad \mathbf{B} = (0, 0, B)e^{i(ky-\omega t)}$$

while $\mathbf{J} = -s\mathbf{A}$ and $\mathbf{E} = i\omega\mathbf{A}$. The divergence and the curl of $\mathbf{A}$ yield

$$\partial_x A_x + ikA_y = 0 \quad \text{and} \quad B = \partial_x A_y - ikA_x$$

We set $A_x = a^{\pm}u^{\pm}(x)$, $A_y = au^{\pm}(x)$ and $B = b^{\pm}u^{\pm}(x)$, where the $+$ and $-$ signs do correspond to $x > 0$ and to $x < 0$ (outside and inside the superconductor). This accounts for the fact that the tangential component of $\mathbf{E}$ has to be continuous, while the amplitude of the oscillations decreases exponentially towards the inside and the outside of the superconducting material: $u^-(x) = e^{\beta x}$ and $u^+(x) = e^{-\gamma x}$, where

$$\gamma a^+ = -\beta a^- = ika, \quad \gamma b^+ = (k^2 - \gamma^2)a \quad \text{and} \quad -\beta b^- = (k^2 - \beta^2)a$$

The purely tangential magnetic field is continuous, when $k^2 = \beta\gamma$ and $b^{\pm} = (\beta - \gamma)a$. No surface current density is required, but the first Equation (6) becomes $\Delta\mathbf{A} - \partial^2_{ct}\mathbf{A} = \alpha^2\mathbf{A}$. This yields the dispersion relation $(\omega/c)^2 = k^2 - \gamma^2$ and $\beta^2 = \alpha^2 - \gamma^2$. We can set $\gamma \approx 0$, $\beta \approx \alpha$ and $\omega \approx ck$. The surface wave is thus nearly propagating at the velocity c and extending far outside the superconductor ($a^- \approx 0$), but the normal component of the electric field is discontinuous at the interface. This yields oscillating surface charge densities, characteristic of surface plasma waves.

6. THE PAIRING MECHANISM

Production of low frequency *stationary* EM surface waves should be verifiable by means of low temperature superconductors. However, this theory applies also to *Unconventional Flying Objects* of unknown origin, since there is evidence that they produce very intense magnetic fields, oscillating at extra-low frequencies [13]. These facts seem to imply that *superconductivity is possible at atmospheric temperature and even higher ones.* That would be of tremendous theoretical and practical importance, but requires the existence of a yet unknown mechanism, gluing two electrons together with a pairing energy $\Delta \approx kT_c$, where T_c is the higher transition temperature.

Any electron repels other electrons and attracts positive ion cores inside a solid. We know that this leads to Debye-Hückel screening, but other processes are also possible. Since ionic motions are slow, they create a wake of positive charge that can attract another electron. This was the basic idea of the BCS theory, where electron pairing was attributed to an exchange of virtual phonons. That accounts for conventional low-temperature superconductivity, but not for *high-T_c superconductivity* (HTS), where the transition temperature T_c is of the order of 100 K. Even 20 years after its discovery, one could say that "the physics behind this strange state of matter remains a mystery" [14]. Many ideas were proposed and experiments yielded so many surprizing results that "we can expect the unexpected" [15]. This justifies even the search for normal temperature superconductivity.

To elucidate the pairing mechanism for HTS, Dal Conte et al. measured the relaxation times in one type of cuprate superconductors for very short pulses of optical excitation [16]. They concluded that electron-phonon interactions contribute much less to the "glue" than *collective electronic excitations,* such as spin fluctuations for instance. Gademaier et al. [17] performed similar measurements for pnictides, cuprates and bismuthates, but they concluded that their T_c depends mainly on the strength of electron-phonon interactions. They added even that the experimental results are only consistent with *bipolaronic pairing.* A polaron is an electron that is accompanied by mobile lattice distorsions, corresponding to a cloud of virtual phonons. Optical phonons have higher energies than acoustic phonons and allow for the formation of small "bipolarons" [18], where two electrons are bound to one another by means of local polarization waves. Today, the theory of superconducting bipolarons is well developed [19, 20]. Although it is quite complex, the basic ideas can be explained in terms a simple model [21]. These ideas were also illustrated by the impotance of the large polarizability of As anions in Fe-based superconductors [22], involving bound electrons.

Normal temperature superconductvity (NTS) seems to require another pairing mechanism. There are already propositions for room-temperature superconductivity [23, 24]. Since layered structures are essential for known high-T_c superconductors and since the present model for the production of very strong low frequency magnetic fields requires only superconductivity for the outer surface of UFOs, it is quite probable that it involves the Electrodynamics of Inhomogeneous Media and Gradient Metamaterials. Moreover, the dielectric constant of free electrons and electron pairs tends toward $-\infty$, when the frequency becomes very small, which has also an effect on image forces. Anyway, the theoretical results presented here, combined with empirical data [1, 13], seem to justify further research of materials that allow for superconductivity at normal atmospheric temperatures and even higher ones.

7. CONCLUSIONS

We found that it is *possible* to generate very intense, low frequency EM surface waves by means of superconducting spheres and that such a system has *remarkable properties.* It is thus important to examine evidence that Unconventional Flying Objects of unknown origin do produce magnetic dipole oscillations of this type. It suggests that *superconductivity is possible at normal temperature and even higher ones,* which justifies the search of a new pairing mechanism of electrons.

It could involve *virtual plasmons* instead of virtual phonons, but we don't know the material that constitutes the external surface of UFOs. Since the type of superconductivity we are considering has only to exist near their outer surface, it may involve surface effects. Anyway, it appears that an objective study of the UFO phenomenon without preconceptions or beliefs is necessary and useful. It raises questions of a new type, which is always important for basic and applied science. It could stimulate the search of normal temperature superconductivity and motivate the conception of new Graded Metamaterials or some other physical process.

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