Quasi-Spherical EMF Polarization

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Abstract – **The paper presents a way of electromagnetic field (EMF) generation that has three spatial components, i.e.: EMF spherical polarized. Such a field is useful in EM susceptibility investigations, especially that of freely moving objects, in electromagnetic compatibility, bioelectromagnetics, etc.**

Keywords – **EMF polarization, spherical polarization**

I. INTRODUCTION

Studies of susceptibility to Electromagnetic field (EMF) are done in different aspects, different objects, in different frequency- and EMF amplitude ranges. Usually linear polarized EMF is applied. As it has already been shown by the authors the approach may lead to remarkable errors in EM energy absorption. In order to measure object's susceptibility in its three spatial axes, the object is rotated. The approach is acceptable while immovable objects are of concern; even in the case an additional procedure (the object rotation) is necessary. In order to simplify the procedure as well as to make it possible to expose objects that can freely move during the exposition a new procedure is proposed. The concept is based upon a possibility to generate an EMF that has three spatial components E_x, E_y and E_z, i.e.: "spherical polarized" EMF. The components are given by following equations:

$$E_x = A \sin \Omega t, \quad (1)$$

$$E_y = B \cos \Omega t \sin \omega t \quad (2)$$

$$E_z = C \cos \Omega t \cos \omega t \quad (3)$$

Where: A, B and C - amplitudes,

Ω - Angular frequency of carrier wave,

ω - Angular frequency of subsidiary LF generator.

II. QUASI-SPHERICAL POLARIZATION

It is not to say that in aspect of physics "the spherical polarization" does not exist. The concept is based upon an idea of circular polarized EMF generation which polarization plane is rotated in space with arbitrary selected frequency ω. A block diagram of a device that allows currents' generation, which may be described by formulas similar to (1), (2) and (3), is presented in Fig.1. The diagram includes a carrier wave generator (G_{CW}) which output voltage is proportional to Sin Ωt. The voltage, thought a $\pm$ 90^o phase shifter, proportional to sin Ωt, is fed to an output amplifier (A) of regulated amplification. If neglect other phase shifts in the channel, it gives at it's output (a) a voltage proportional to sin Ωt (see eq.1). Simultaneously the output voltage of the CW generator is fed to two balanced mixers (M).

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A subsidiary low frequency generator (G_{LF}) generates voltage proportional to cos ωt. The voltage is fed directly to lower balanced mixer. It's output voltage is a product of the both fed voltages and it is proportional to cos Ωt cos ωt (see eq.3). After amplification, in similar conditions as above, a voltage proportional to cos Ωt cos ωt is fed to output of the channel (c). A voltage from LF generator, throught a $\pm$ 90^o phase shifter, proportional to sin ωt, is fed to upper balanced mixer. A product of voltages fed to the mixer is proportional to: cos Ωt sin ωt (see eq.2). Then, the voltage after amplification, is fed to the output of channel (b).

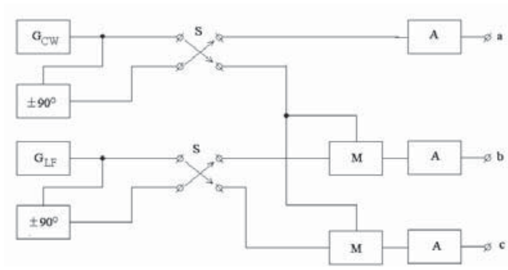

Fig. 1. Block diagram of the generating device
Legend: G_{CW} and G_{LF} – carrier wave and subsidiary LF generator, M – balanced mixer, A – amplifier.

Voltages from the generator may be applied for excitation of an EMF field source. Below we present three possibilities. In Fig. 2 is shown a set of three mutually perpendicular loops. Separate loops are fed from the three channels of above described generator. The set allows a quasi-spherical H-field generation inside the set. Because of evident reasons the set may be exploited at rather low frequencies.

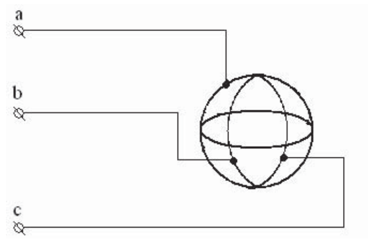

Fig. 2. Three mutually perpendicular loops

Fig.3 presents a set of three mutually perpendicular plate capacitors. Each pair of plates is fed from separate channel of the generating device. In the set a generation of quasi-spherical polarized E-field is possible. Mutual couplings between the capacitors as well as standing waves on the plates limit the application of the set to low frequencies. A disadvantage of the sets presented in Fig. 2 and 3 is quite small volume where the field may be assumed as homogeneous. Their advantage is a possibility to excite them in wide frequency LF range.

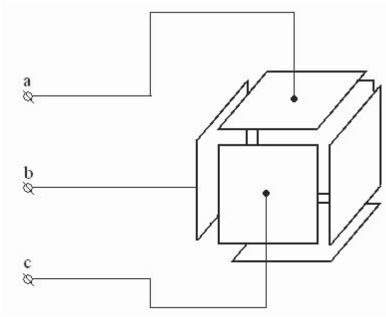

Fig. 3 Three mutually perpendicular capacitors

In Fig. 4 a set that may be applied at high frequencies is presented. The set consists of three log-periodic antennas. Two of them, perpendicular one to each other, are coupled together, as it is usually done with antennas radiating circular (elliptical) polarized EMF. The third is in plane perpendicular to that of previous ones and axes of radiation of the antennas cross themselves in a point of observation (O). The antennas are at distance R from the point O. The distance should fulfil following requirement: $R \geq 2d^2/\lambda$ (where d is maximal size in the system and λ is wavelength). The requirement reflects known condition of the far-field boundary. The antennas are fed from three channels of the generating device. As a result around point O we have quasi-spherical polarized EMF and, if the condition is fulfilled, the field has a structure of the plane wave. Contrary to two previously presented sets this one should be used within an anechoic chamber in order to limit interference radiated outside (often investigations are performed with power at level of kilowatts or more) and field deformations due to propagation phenomena (reflections, multipath propagation).

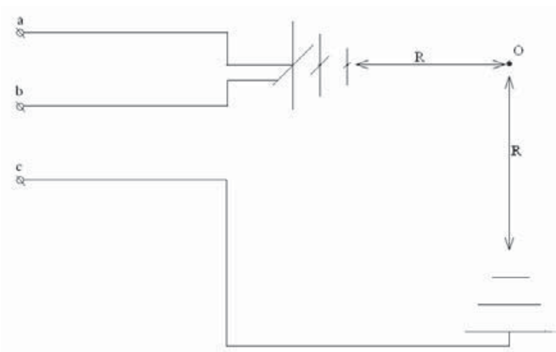

Fig. 4 Three mutually perpendicular log-periodic antennas

If assume identical amplitudes (e.g.: A) at the output of the three channels and linear dependence between the voltages fed to one of presented sets, the amplitude of the resultant E-field is expressed by following formula:

$$E = A\sqrt{\sin^2 \Omega t + \cos^2 \Omega t \sin^2 \omega t + \cos^2 \Omega t \cos^2 \omega t}$$

As it is easy to see from the formula: E = A. It means that we have an E-field component that has three identical spatial components and the resultant field is independent of spatial coordinates of the field.

III. FINAL COMMENTS

The paper presents new method of EMF generation that allows obtaining a field with arbitrary polarization. Lets see:

- Linear polarized field, in one of three perpendicular axes, exists if assume, for instance, B = C = 0. In the way of small modification of the generating device it is possible to have linear polarized field in arbitrary direction.
- Circular polarized field will appear if assume, for instance, A = B, C = 0.
- Elliptical polarized field we'll have in conditions as above if $A \neq B$.
- Spherical polarization requires A = B = C.
- Ellipsoidal polarization is while $A \neq B \neq C$ and different combinations are here possible.

These are not all possibilities of the set. Namely:

- Upper switch allows a change of "right hand polarization" to the left hand's one of the carrier wave excited signal.
- Lower switch allows a change of the circle (ellipse) polarization plane rotations. Per analogy to the above we may call it "right hand rotations" and "left hand rotations".
- An axis of the circle (ellipse) polarization rotations may be switched by different connections of the generating device with a field generating system, for instance: a to a, b to b and c to c, or: a to b, b to c and c to a, etc.

As it could be seen from the above the set allows a lot of polarization's combinations. We did not take into considerations amplitude of the generated field, as it was not of concern. The amplitude is a function of power that will be delivered to applied set of radiators. The only comment, as regards as the amplitude, may be related to necessary staff protection against EM radiation as well as interference radiation into surroundings.

Presented possibility of the EMF generation may be of concern in any experimental research in generally understood electromagnetic compatibility. Its application is especially suggested in the case of studies in bioelectromagnetics. The latter are loaded with large exposure estimation error due to usually unknown polarization of used field, mutual couplings between exposed objects and between the objects and an exposure system as well as errors in exposure effects estimations due to immobilization of exposed animals. An application of the set in bioelectromagnetics leads to remarkable limitation of simultaneously exposed animals. However, it may lead to an agreement of results of "similar" experiments in different labs. Now the results are different very often that leads to misinterpretation of studied phenomena and misunderstandings.

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