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Applications of Hexagonal Ferrites in Ultra High Frequency Range Especially in GHz Range

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Abstract
In the communication sector, ferrites have been playing a crucial role for last three decades. In the present times, hexaferrites especially CO_2Z hexaferrite finds its potential application in GHz range i.e., in 3G and 4G spectrum. The beauty of CO_2Z hexaferrite is that it is magnetically soft and structurally hexagonal in nature. These can be synthesized by soft chemical route especially Sol-Gel or Auto Combustion method in a controlled manner at a much lower temperature than that required for existing hexaferrites. Their magnetic/microwave properties can be controlled by varying the size of the CO_2Z hexaferrite. In this paper we have investigated use of hexaferrite for high frequency signal transmission. Optimization of electromagnetic properties of hexaferrite is required so as to make best use of these materials for electronics and communication technologies.

Keywords
Hexaferrite, 3G&4G Communication, High Frequency Siganal

I. Introduction

Richard Feynman (Feynman, 2005) once stated that ferrites were one of the most difficult areas for theoretical description, but the most interesting for studies and practical applications. These words are especially true when dealing with a special type of ferrites, which have a hexagonal crystallographic structure – hexagonal ferrites, or hexaferrites.

The world's first permanent magnets based on ferroxdure - hexagonal barium ferrite BaFe12O19 (equivalent to BaO·6(Fe2O3), also called BaM) appeared in 1951. The main engineering problem that was solved at that time was the replacement of cumbersome metallic (Ni- and Co-alloy) magnets by comparatively compact and light- weight permanent magnetic systems. The detailed study and applications of gyro magnetic properties of hexaferrites started in 1955. Currently, in the world, enormous progress in fundamental theoretical and experimental laboratory studies of various properties of hexaferrites, their synthesis, and engineering of a wide range of microwave and mm-wave coatings and devices on their basis has been achieved [1-2].

Unfortunately, the achievements in the field of Hexa ferrite could not be published in open literature with wide international access for many decades. Very limited number of papers on this topic were published. The objective of the present paper is to cover this gap, and allow researchers to get acquainted with these works not only from retrospective point of view. They contain the present-day novelty, and can be useful for engineers designing electronic equipment operating in a wide frequency range from about 2 GHz to 300 GHz, and potentially even higher. An application of hexagonal ferrites is proven and remains very perspective for solving numerous problems related to microwave engineering, radar engineering, electromagnetic compatibility (EMC), electromagnetic immunity (EMI), and signal integrity (SI). Hexaferrites can be used for detection and suppression of unwanted radiation and coupling paths; for frequency-selective measurements of signal parameters; and for providing proper non-reciprocal isolation in channels of generation, transmission, and reception over the selected frequency bands within the wide range up to a few hundred GHz.

II. Hexagonal Ferrites as Advanced Ceramic Materials for Microwave and Millimeter Wave Engineering

Hexaferrites are known to be magneto-dielectric, specifically ferromagnetic materials with hexagonal magneto plumbite-type crystallographic structure [3]. Ferri-magnetic magneto-plumbite has the general chemical formula MeO·6Fe2O3, in which Me may be Ba2+, Sr2+, or Pb2+. The ferric ions can be also partially replaced by Al3+, Ga3+, Cr3+, Sc3+, or combinations of ions, for example, Co2+ with Ti4+, Zn2+ with Ti4+, etc. Hexagonal ferrites, unlike the other groups of ferrites (spinels and garnets), have a pronounced internal effective magnetic field HA, associated with the magnetic crystallographic anisotropy. From a crystallographic point of view, a hexaferrite is characterized by the hexagonal basis plane and the axis of symmetry that is orthogonal to the basis plane.

Monocrystalline and polycrystalline magnetically uniaxial hexaferrites are the most widely used in practical applications. Polycrystalline uniaxial hexaferrites are commercially available. As for planar hexaferrites, the possibilities of studying them are limited because of low Curie temperatures. The concept of a field of magnetic crystallographic anisotropy, or briefly called "anisotropy field", is widely used for phenomenological description of hexaferrite behavior. It is calculated approximately as (Gurevich & Melkov, 1996)

$$HA \approx 2|K1| / Ms \qquad (1)$$

where Ms is th saturation magnetization, and K1 is the first constantof anisotropy,

The crystallographic magnetic anisotropy field determines the conditions for ferrimagnetic (gyromagnetic) resonance (FMR) in hexagonal ferrites. The resonance frequency of a magneto-uniaxial ferrite is related to the magnetization field and orientation of a equilibrium magnetic moment with respect to the constant bias magnetic field. Boris magnetized in the easy direction, appears to be dozens times lower than when using ordinary, low-anisotropy ferrites. Thus, for the uniaxial ferrites, the applied bias field to achieve the resonance frequency ωres is (Kittel, 1948)

1. The first stage the attempts to synthesize, in the laboratory conditions, different types of ferrites with various fields of crystallographic anisotropy, test their charactristics, and build devices of EHF (30...300 GHz) frequency band on their basis.
2. The second stage was focused on the improvement and optimization of the synthesized materials from the point of view of practical applications, as well as engineering of the advanced designs of microwave and mm-waved devices.
3. The third stage was developing and producing industrial series

of the engineered ferrites of different types and devices on their basis using the facilities of the electronics industry.

The work on the synthesis of magneto-uniaxial ferrites was mainly done in two directions:

One is synthesis of ferrites with different anisotropy fields to be able to design devices for different frequency bands, and second is an optimization of required properties. Engineering and application of hexagonal ferrite films for the EHF (30-300 GHz) resonance and wideband devices operating without any bias magnetic field is an important advance in improvement and simplification of the manufacturing processes.

A mixture of a few types of hexaferrite powders differing by their anisotropy fields can be used to make multiphase composites. They typically have a greater width of the FMR, which is favorable for developing resonance isolators or other devices operating over a wider frequency range. Films based on hexaferrite composites exhibit higher coercivity, which allows for operating without any external bias magnets in the frequency range up to 100 GHz. Another important feature is their comparatively low permittivity, which provides better matching of films with the other dielectric elements in a microwave (mm-wave) transmission line. Besides, it is much easier and cheaper to manufacture such films than the bulk plates. The requirement of having an extremely small thickness is not difficult to satisfy, since the chip technology can be used for their manufacturing, and these films can be used in microwave chips, though there may be problems at the interfaces with other materials. Moreover, when dealing with polycrystalline hexaferrite powders, the control of the ferrite contents at different stages of their manufacturing, is substantially simplified. It is possible to do without making special test samples – plates of thickness less than 0.1 mm, or spheres of at least of 0.4 mm in diameter to apply the standard techniques for measuring intrinsic parameters of ferrites. Also, there is no necessity of texturizing samples for study, and no need in bias field for measurements.
We are in the process of preparing such ferrites at RKMV shimla, Himachal Pradesh (India) by soft chemical method [4-7]. Since Barrium hexa ferrites were first developed [8], these were effectively used for high density magnetic recording [9] due to better magnetic prperties. The electromagnetic properties, particularly imaginary and real part of permittivity and permeability are being investigated for various compositions. For high speed communication devices it is required that real part of permittivity and permeability value should be >2 and imaginary part should approach zero. Z.W. Li et.al. 10] have investigated high-frequency properties and EM wave attenuation for some compositions of hexaferrite system. We have investigated such ferrites by doping these with strontium, zinc, nickel and magnesium etc. prepared by soft chemical route.

III. Conclusion

During past four to five years production of electronic devices operating at high frequency has increased. Hexaferrite materials have become commercially and technologically very important material. Antenna made by hexaferrite material offers best solution for this purpose. Permittivity and permeability are two important properties of hexaferrite which can be adjusted by changing composition and method of hexaferrite. This will bring revolution in the electronic and communication industry

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