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To cite this version:
Lj. Živanov, P. Nikolić, O. Aleksić. THICK FILM MM-WAVE ISOLATOR. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-2021-C8-2022. <10.1051/jphyscol:19888918>. <jpa-00229188>

HAL Id: jpa-00229188
https://hal.archives-ouvertes.fr/jpa-00229188
Submitted on 1 Jan 1988

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THICK FILM MM-WAVE ISOLATOR

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Abstract. — Promising preliminary results are presented for an isolator in finline structure using hexaferrite thick film. The nonreciprocal properties of this structure were measured in the frequency range 44–50 GHz. The experimental results exhibited an isolation in excess of 30 dB between 47.7 and 49 GHz. At 48.5 GHz the forward-to-backward ratio was greater than 20. It is suggested that such structures would be suitable for higher frequencies.

1. Introduction

In order to exploit the potentials of the mm-wave region of the em spectrum, nonreciprocal components have still to be developed. The first attempts to construct a mm-wave isolator was realized as a waveguide resonance isolator [1, 2]. However, for this kind of isolator operating at mm-wave frequencies, a strong magnetic bias field or an anisotropic ferrite would normally be required together with a small dimensions of the ferrite slab. In the last twenty years several methods for constructing mm-wave isolators have been investigated. It was demonstrated a new form of ferrite devices using technology of mm-wave image line integrated circuits [3, 4]. Recently, a new finline ferrite isolator for integrated mm-wave circuit has been developed by several researchers [5–7]. A nonreciprocal devices in fin line technique are of great interest in the mm-wave region because other devices have already been realized in the frequency range of 8–170 GHz, successfully. As it is expected that a deposition of ferrite to form thick film may be a method of achieving geometries and tolerances necessary for mm-wave devices, it was our intention to construct a thick film finline mm-wave isolator. The experimental result of this kind isolator in the range from 30 to 40 GHz was reported in [8, 9].

The purpose of this paper is to present our work by extending the frequency range beyond 40 GHz. The investigation have two parts: the first is to produce high quality thick films, from barium and strontium hexaferrite and the second part is to design and make fin line isolators.

2. Preparation of hexaferrite thick film

Thick film hexaferrite paste was prepared by mixing together an 95 wt % of Ba- or Sr- hexaferrite powder and 5 wt % binder glass powder (Pb2O3, SiO2 and B2O3) and organic vehicle. The amount of the glass added were controlled in order to provide the paste with good adhesion to substrate and suitable magnetic properties. That are two conflicting requirements. Average particle size of powder is less than 1.5 μm. Figure 1 shows the preparation process of hexaferrite pastes.

The hexaferrite layers were printed with 200-mesh screen (stainless steel) and fired at 850 °C for 10 min. The thickness of hexaferrite layer is about 15 μm. Figure 2 summarizes the thick-film fabrication processes.

3. Experimental mm-wave isolator

Our basis idea consisted in replacing the ferrite slab with ferrite film in existing fin line isolators [5]. The analysis presented in [10] enabled estimation of magnetic characteristics of the hexaferrite film and their selection for constructing a mm-wave fin line isolator. Typical properties of the hexaferrite pastes are: residual magnetization is about 200 mT and coercive force.
is about 96 KA/m. With regard to the thickness of the ferrite slab used in existing mm-wave isolators we decided to use a multiple printing. Anisotropic properties of the thick film were achieved by using a dc magnetic field parallel to the substrate during the depositing and drying process. A thick film of hexaferrite (0.2 mm) was deposited on the substrate surface of the fin line circuit and was magnetized parallel with the substrate by field 0.2 T.

Fig. 3. – Experimental prototype of a thick-film fin-line isolator.

An alumina substrate was 0.63 mm thick. The performance characteristics of the designed fin line isolators were measured using the setup presented in [9]. The measured transmission (with crosses) and isolation (open dot) loss of the Ba-hexaferrite thick film isolator in frequency range from 44 to 50 GHz are shown in figure 4. The bandwidth over which the isolation loss is greater than 30 dB is about 2 GHz (around 48.5 GHz).

Fig. 4. – The performance characteristics of a thick film isolator.

4. Discussion

Recently, the theoretical analysis of double layered fin-lines [11] has confirmed that the dielectric layer introduced between the fin and the ferrite layer can improve the nonreciprocal characteristics. Our investigations have shown that is possible to operate thick-film fin line isolator without external magnetic field in frequency range from 30 th 40 GHz but not beyond 40 GHz. It is connected with a quality of hexaferrite thick film and their magnetic properties. A small external direct magnetic field is provided to orientate the internal field along the positive or negative c-axis of the uniaxial ferrite material and for tuning purpose beyond 40 GHz.

The band width of the resonance isolator can be widened by tapering the direct magnetic field or by either cascading or stacking ferrite layers with different values of magnetisation and anisotropy field. It will be next step in our further investigation.

5. Conclusion

The advantage of this kind isolator is that it can be fabricated at low cost through the use screen-printed process. This method of the fabrication allow a significant size and weight reduction and achieving a high degree of reproducibility and so on.