YIG RESONATOR CIRCUIT WITH ISOLATOR PROPERTY AND ITS APPLICATION TO GUNN DIODE OSCILLATOR

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ABSTRACT

This paper presents analysis and experiments of a newly developed YIG resonator circuit with isolator property, which is constructed with a YIG sphere, a 3 dB directional coupler and three coupling loops. The paper then goes on to describe experiments of a magnetically tunable Gunn diode oscillator with the YIG circuit. It has been confirmed that the YIG circuit applied to a tunable oscillator is useful in frequency pulling and in the variation of output power level.

Introduction

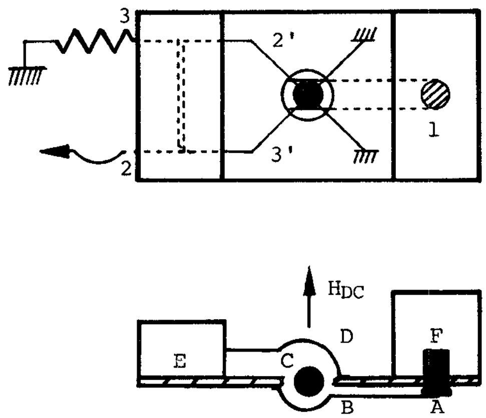
It is well known that frequency and output power level of an oscillator are usually affected by reflection from a load. Thus in lower microwave frequency bands a buffer amplifier is used and in higher microwave frequency bands an isolator or a circulator is required. A YIG resonator is commonly used as a magnetically tunable element in wide band microwave sweep oscillator. In such a sweep oscillator, it is necessary to use additionally a wide band isolator or circulator, as these are disadvantageous in size and cost it is desiable to use a YIG element which has both resonator and isolator properties at the same time.

One of the authors already reported such a kind of waveguide type YIG resonator circuit[1]. This waveguide type circuit, however, is inferior in size and band width. Then a new YIG resonator circuit with isolator property has been developed that is combined with a YIG resonator sphere and a 3 dB stripline type directional coupler. This paper presents analysis and experimental confirmation of the new YIG resonator circuit with isolator property, and then its application to a magnetically tunable Gunn diode oscillator. The value of calculated scattering matrix of the YIG circuit agrees well with expermental results, and the magnetically tunable Gunn diode oscillator shows good improvement in frequency pulling and in output power level change due to load variation.

YIG resonator circuit with isolator property

Fig.1 is a schematic of the YIG resonator circuit combined with a Gunn diode. The loop from port 1 is tightly coupled to a YIG sphere, so the YIG sphere is used as a resonator when an active element is connected to port 1 . The output port of an X-form orthogonal coupling, which is not coupled directly to the loop of port 1 , are connected to port 2' and 3' of a 3 dB directional coupler, similar to a nonreciprocal filter[2,3]. The output power of the resonator is led to port 2' and 3' of the 3 dB directional coupler. The coupled rf magnetic fields to port 2' and 3' have $\pi/2$ - phase difference to each other. Thus the output power of the 3 dB directional coupler is led to only port 2 .
A reflected power from port 2 is a negative polalized field at the YIG sphere, then not coupled to the YIG sphere, but led to the matched termination of port 3 .

A scattering matrix (S_{DY}) against port 1 , 2 and 3 in the same figure is obtained as follows by considering scattering matrics of the 3 dB directional coupler and the X-form coupling part.



A : Gunn Diode B : Diode Loop
C : YIG Sphere D : Output Loop
E : 3dB Coupler F : Heat Sink

Fig. 1. Schematic of YIG resonator circuit with isolator property.

$$
(S_{DY}) = \begin{bmatrix}
1-\frac{2Q_\ell}{Q_{ex1}}, & \frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex2}}}\alpha - j\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex3}}}\beta, & \frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex2}}}\beta - j\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex3}}}\alpha \\
\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex2}}}\alpha + j\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex3}}}\beta, & \left(1-\frac{2Q_\ell}{Q_{ex2}}\right)\alpha^2 + \left(1-\frac{2Q_\ell}{Q_{ex3}}\right)\beta^2, & 2\alpha\beta\left(1-\frac{Q_\ell}{Q_{ex2}}-\frac{Q_\ell}{Q_{ex3}}\right) + j\frac{2Q_\ell}{\sqrt{Q_{ex2}Q_{ex3}}}(\alpha^2-\beta^2) \\
\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex2}}}\beta + j\frac{2Q_\ell}{\sqrt{Q_{ex1}Q_{ex3}}}\alpha, & 2\alpha\beta\left(1-\frac{Q_\ell}{Q_{ex2}}-\frac{Q_\ell}{Q_{ex3}}\right) + j\frac{2Q_\ell}{\sqrt{Q_{ex2}Q_{ex3}}}(\beta^2-\alpha^2), & \left(1-\frac{2Q_\ell}{Q_{ex2}}\right)\beta^2 + \left(1-\frac{2Q_\ell}{Q_{ex3}}\right)\alpha^2
\end{bmatrix}
$$

$$
\frac{1}{Q_\ell} = \frac{1}{Q_o} + \frac{1}{Q_{ex1}} + \frac{1}{Q_{ex2}} + \frac{1}{Q_{ex3}}
$$

where Q_ℓ is the loaded Q of the YIG resonator circuit, Q_{ex1}, Q_{ex2} and Q_{ex3} are the external Q of port 1 , 2' and 3', respectively and Q_o is the unloaded Q of the resonator, $\alpha = 1/\sqrt{2}$ and $\beta = -j\,1/\sqrt{2}$ for a perfect 3 dB directional coupler.

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As shown is the equation, S_{12} is equal to zero and S_{21} is not S_{12} when a value of Q_{ex2} is equal to that of Q_{ex3}, so the equation shows that the YIG resonator circuit has isolator property.
The calulated values of S_{ij} from the equation by using measured values of Q_o, $Q_{ex1} \sim Q_{ex3}$ shows good agreement with those measured directly. The measured absolute values of the elements of (S_{DY}) are shown in Fig. 2 .

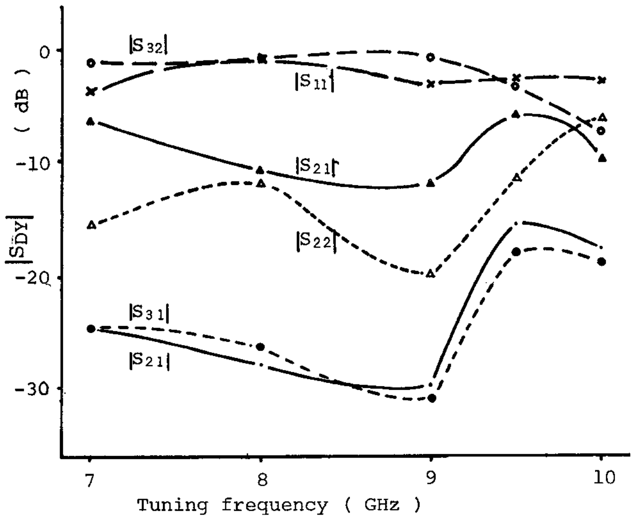

Fig. 2. $|S_{DY}|$ against tuning frequency for YIG resonator circuit.

From the figure, isolation between port 1 and port 2 is more than 15 dB from 7 GHz to 9 GHz , but above 9 GHz , isolation somewhat degraded. This is caused by the characteristics of the 3 dB directional coupler being used.

The non-linear effect is not recognized up to 16 dBm of the output power level from the YIG resonator being used.

Magnetically - tunable Gunn diode oscillator

A magnetically tunable Gunn diode oscillator is designed and evaluated by using the above mentioned YIG resonator with an isolator property circuit and a Gunn diode. A Gunn diode is connected to port 1 in Fig. 1 . A coupling loop at port 1 is tightly coupled to a YIG sphere.

The designing of the oscillator is done by measuring both the hegative resistance of the Gunn diode and the resonance curves of the YIG resonator circuit from port 1[4].
The diameter of a YIG sphere used is 1.5 mmϕ, saturation magnetization is 1780G and the Gunn diode is an AEI. DI 1281G. A coupling semi loop connected to port 1 is a riddon with 3 mm width, and a diameter $\phi = 2$ mm. The experimental results of the magnetically tunable Gunn diode oscillator are shown in Fig. 3 . In the figure, curves 2 shows output power levels at output port 2, and curve 3 is leakage power level ot the matched termination of port 3. The output power level of the oscillator is about 10 dB to 16 dBm from 7 GHz to 9.2 GHz.
The relation between oscillation frequency and an applied dc magnetic field is linear from 7 GHz to 10 GHz, and the power level of spurious frequency is below -50 dBm .
Curves A and B indicate the frequency variation Δf due to phase-change of the output load when reflection coefficient of the load $|\Gamma| = 1$. Curve A shows the data of the utilization of the YIG resonator circuit with isolator property, and curve B is the case of the usual YIG resonator. In the case of the YIG resonator circuit with isolator property the value of Δf is below 2 MHz. For the usual YIG resonator the maximum value of Δf is about 15 MHz. In the new YIG circuit, despite changes in the loading of the oscillator, power output variation of the oscillator is held to a level below 1 dB range. In the case of the usual YIG circuit, this level varied widely and when loading become critical the oscillator effectively ceased operating.

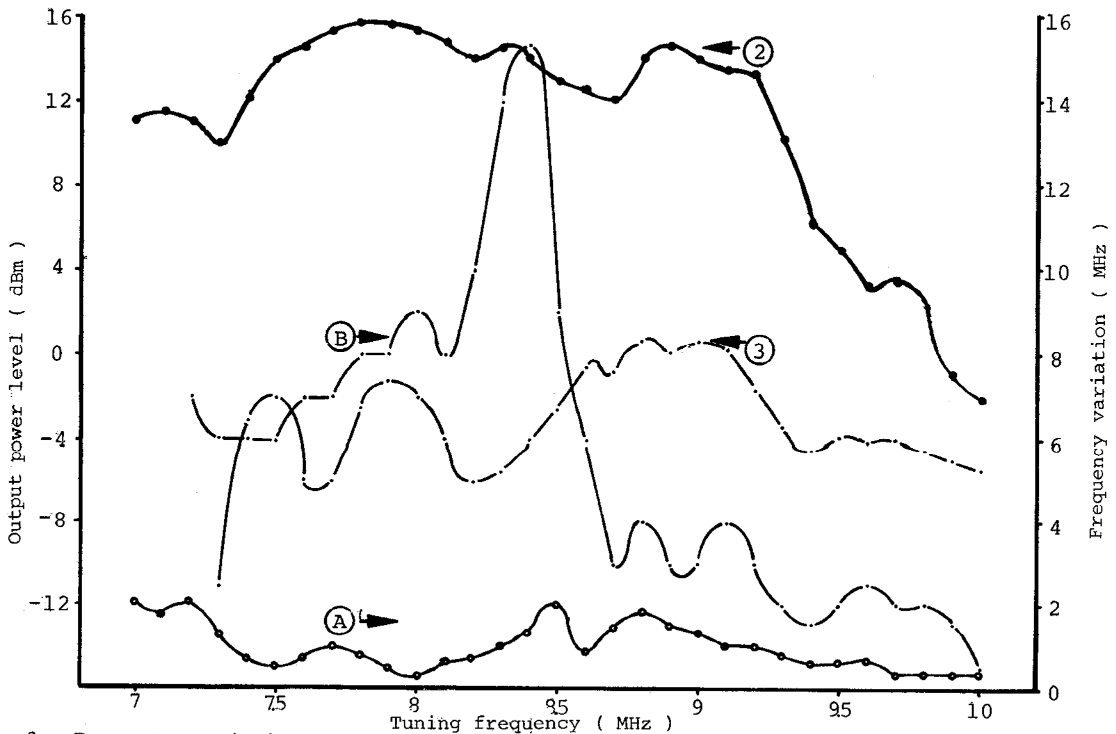

Fig. 3. Frequency-variation due to the change of load-phase and output power level against tuning frequency of the Gunn diode oscillator with the YIG resonator circuit.

Conclusion

It has been ascertained that the YIG resonator circuit with isolator property is useful for preventing frequency pulling and power level variation of an oscillator due to change of its load, is superior in cost and size. The obtained scattering matrix is confirmed by experiment. A tunable frequency range of the oscillator with the YIG resonator circuit can be made wider when a wider frequency band 3 dB directional coupler is utilized.
The proposed YIG resonator circuit will be naturally applicable to other negative resistance type oscillators like that of Impatt diode oscillator, but for the application to the more high power oscillator, some careful considerations about non-linear effect will be required.

Acknowlegements

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