A Dielectric Resonator Stabilized Frqeuency Modulation Oscillator in the S-Band

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ABSTRACT

With the development of the airborne telemetry technigue, it will be demanded that the transmitting sets on the missiles are more reliable and smaller. A frequency modulation (FM) oscillator stabilized with a dielectric resonator (DR), which can operates in the S-band directly, is presented. The FM oscillator is of simple circuit, reliable operation in the stabilization, small size, light weight and low cost. It will have a certain prospect of application in the airborne telemetry transmitting sets.

Key word: Airborne Telemetry, Dielectric resonator, Frequency modulation oscillator

I. Introduction

In 1939, R.D.Richtemeyer first affirmed in theory that the dielectric might be acted as the electrical resonator which is called the dielectric resonator (DR). Since DR has a very high dielectric constant, its size is several or even tens times smaller than the metal cavity resonator. It is this that it is necessary to realize the smallization of microwave resonators and the intergration of microwave devices. In the recent decade, the DR technique has been becoming mature in nation and internation. with emerging of it which has high Q value and a series of temperature coefficients, DR is widely used in the microwave solid state oscillating sources and filters.

At present some researchers are devoting themself to expanding the application fields of the dielectric resonator. The reference 3 presented a microwave modulator (FM oscillator) stabilized with DR at 4 GHz or 6 GHz, it had been applied successfully in the microwave communication and satellite communication. In order to expand the application of DR technique to airbone telemetry transmitters, this paper will probe into the research project on the FM oscillator stabilized with DR in the S-band.

2. Circuit structure and working principle of FM oscillator stabilized with DR

Figure 1 shows the circuit principle diagram of FM oscillator which is stabilized with DR, its central frequency is in the S-band. This circuit is separated into two parts as follows:

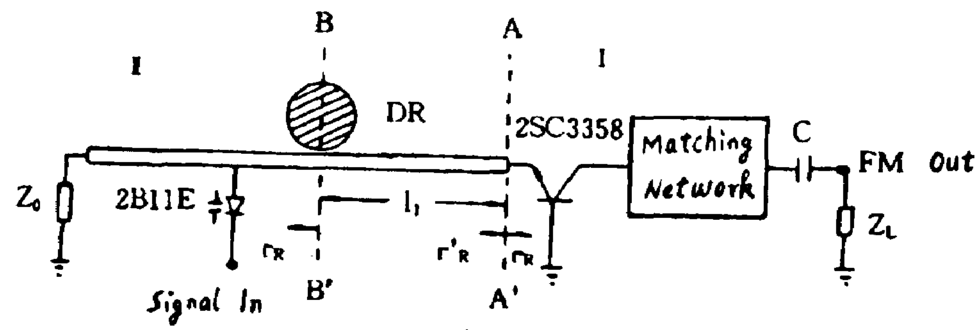


Fig. 1 Circuit principle diagram of FM oscillator stabilized with DR

First is the network I. It contains a low noise bipolar transistor 2SC3358, an output match network, an isolating capacitor and a load.

Second is the network **I**. It consists of a DR, a capacity—varing diode 2B11E, an input microstrip line and a resistor Z_0. DR is placed in the side of the microstrip line which characteristic impedance is 50Ω, and is l_1 long away from one end A-A′ of the network I. At the central operation frequency, DR reflects the input signal coming from the transistor as if it is a reflective dielectric resonating cavity, so constituting a reflective dielectric resonator—oscillator.

In the network Ⅱ, when a varing modulating—signal is applied to the capacity—varing diode 2B11E, its capacity will be changed. This capacity reflects into the dielectric resonator so that the resonat frequency of DR is varied, then resulting the fresuency modulation.

3. The design of DR in the S-band

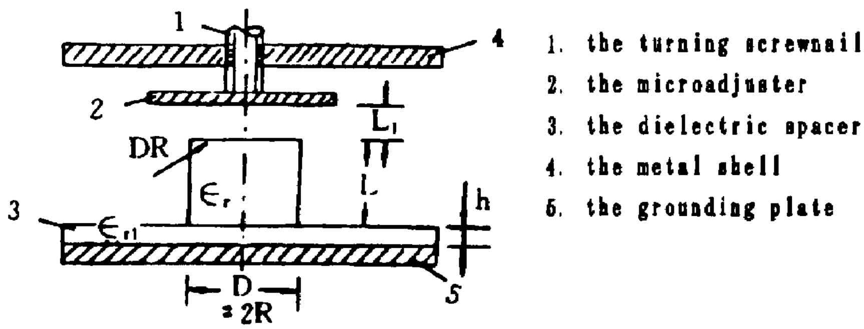


Fig. 2 The structure of DR on the microstrip substrate

The structure of the cylintric dielectric resonator on the microstrip substrate is shown in Figure 2. DR operats in the lowest pattern $TE_{01\delta}$. There are many methods analysing the frequency of DR in the $TE_{01\delta}$. Such as are the magnetic wall, the open-waveguide, the revising open-waveguide, the calculus of variation, and so on. Among, the revising open-waveguide analysis is more applicable and welcome in the engineering applications than others, because its calculating precision (1%) and complicated degree is more moderate.

With the revising open-waveguide analysis, We can obtain a set of feature equations of DR resonance frequency as follows

$$\frac{J_1(u)}{uJ_0(u)} + \frac{K_1(v)}{vK_0(v)} = 0$$

$$u^2+v^2=\frac{\varepsilon_r-1}{\varepsilon_r}F_0^2 \qquad (1)$$

$$\frac{L}{R}\sqrt{F_0^2+v^2} = tg^{-1}\frac{\sqrt{\rho_{01}^2-F_0^2/\varepsilon_r}}{\sqrt{F_0^2+v^2}\,(\frac{L_1}{R}\sqrt{\rho_{01}^2-F_0^2/\varepsilon_r})}$$

$$+tg^{-1}\frac{\sqrt{\rho_{01}^2-\varepsilon_{r1}F_0^2/\varepsilon_r}}{\sqrt{F_0^2+v^2}\;th(\frac{L_1}{R}\sqrt{\rho_{01}^2-\varepsilon_{r1}F_0^2/\varepsilon_r})}$$

$$F_0^2=\frac{2\pi r f_0}{v_0}\sqrt{\varepsilon_r}$$

Where,

ρ_{01}: first root value of Jo(x), it is 2.408;

ε_r: the relative constant of DR;

ε_{r1}: the relative dielectric constant of the dielectric spacer;

f_0: the resonance frequency of DR.

Known the resonance frequency f_0 of DR, and after selecting ε_{r1}, h, ε_r, R and L_1, we can calculate the height L of DR from equation sets (1). When calculating, we use the unfolding formulas gradually for the Besel functions $J_0(u)$, $J_1(u)$, and the revising Besel fumctions $K_0(v)$, $K_1(v)$ in first formula.

While ε_r, R and fo have been selected, $(\varepsilon_r-1)F_0^2/\varepsilon_r$ is a constant value. Thus we may simplify first and second formulas of equation sets (1) into a surpassing equation

$$F(u) = 0 \qquad (2)$$

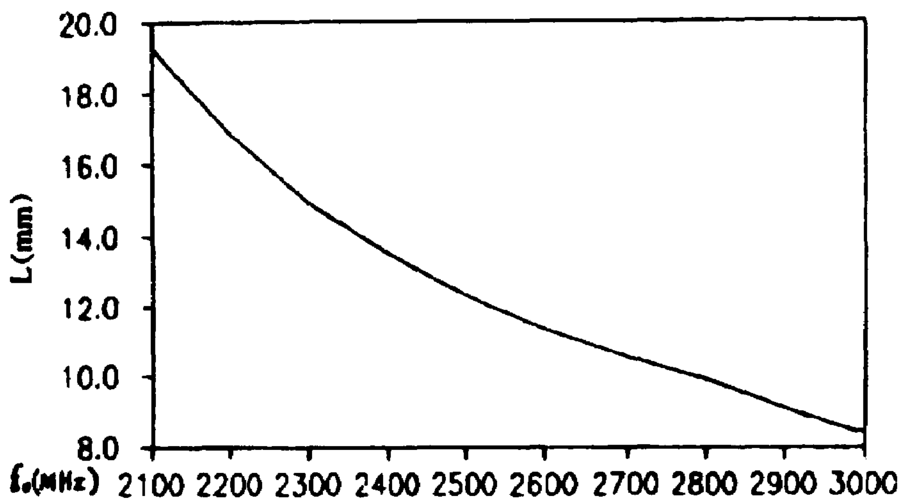
The reference 2 had given an approximate formula drawing out from equation sets (1)

$$u= 0.951\rho_{01}+0.222\sqrt{\frac{\varepsilon_r-1}{\varepsilon_r}F_0^2-0.95\rho_{01}^2} \qquad (3)$$

In order to increase further the calculation precision, the formula (3) is needed to make some revision. In the course of the revision, we first draw out the curve graph of the function F(u), and find out u_0 and u_1 near the cross-point of F(u) with u axis in this graph. Then, with the duality method, we carry on the repeated algebraic operations and acquire the precise value of u. Finally, comparing this precise value with the calculating result of formula (3), it is seen that the former is 0.015 greater than the latter. For this reason, a revising approximate formula can be get

$$u = 0.951\rho_{01} + 0.222\sqrt{\frac{\varepsilon_r - 1}{\varepsilon_r}F_0^2 - 0.95\rho_{01}^2} + 0.015 \qquad (4)$$

After calculating u value, with known parameters, the height L of DR can be gained from the third formula of equation sets (1). Therefore entire calculations is simplified. Figure 3 gives a calcuating curve graph of f_0 corresponding L. A DR can be desingned by using this graph.



Known: $\varepsilon_r = 38$, R=12mm, h=1mm, $\varepsilon_{r1} = 9.6$, L_1 = 3mm

Fig. 3 The design curve of DR in the S-band

4. The design of FM oscillator

Figure 4 shows the circuit pattern of FM oscillaor and its equivalent circuit with Z parameters. Where, Z'_R is converted from DR,

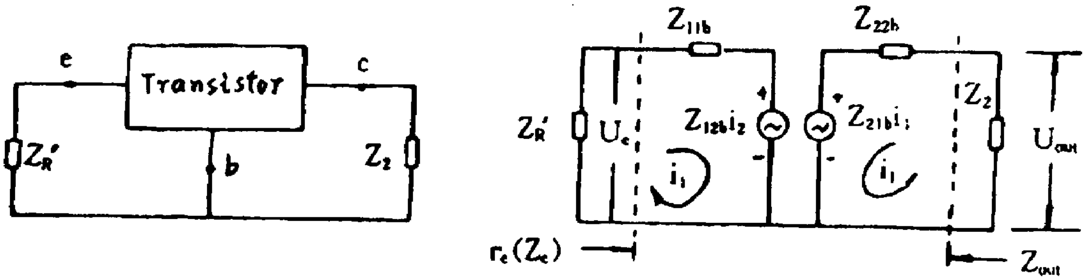


Fig. 4 (a) The pattern of a common-base circuit
(b) Its equivalent circuit with Z parameters

the diode and Z_0 through the microstrip line which length is l_1. The determination of $[Z]_b$ is as follows

$$Z_{11b}=\frac{(1+S_{11b})(1-S_{22b})+S_{12b}S_{21b}}{(1-S_{11b})(1-S_{22b})-S_{12b}S_{21b}}Z_0$$
$$Z_{12b}=\frac{2S_{12b}}{(1-S_{11b})(1-S_{22b})-S_{12b}S_{21b}}Z_0 \qquad (5)$$
$$Z_{21b}=\frac{2S_{12b}}{(1-S_{11b})(-1S_{22b})-S_{12b}S_{21b}}Z_0$$
$$Z_{22b}=\frac{(1-S_{11b})(1+S_{22b})+S_{12b}S_{21b}}{(1-S_{11b})(1-S_{22b})-S_{12b}S_{21b}}Z_0$$

In the formulas mentioned as above, $[S]_b$ is transformed from the known $[S]_e$ through the indefinite scattering matrix $[S]_{3\times 3}$.

We can get from Figure 4(b)

$$Z_e=\frac{U_e}{i_1}=Z_{11b}-\frac{Z_{12b}Z_{21b}}{Z_{22b}+Z_2}$$
$$\Gamma_e=\frac{Z_e-Z_0}{Z_e+Z_0} = \Gamma_e e^{i\Phi_e} \qquad (6)$$
$$Z_{out}=\frac{U_{out}}{i_2}=Z_{22b}-\frac{Z_{12b}Z_{21b}}{Z_{22b}+Z_R'}$$

Where, Z_2 and Z_{out} must satisfy following equation

$$R_e(Z_2) = - R_e(Z_{out})/3 \qquad (7)$$
$$I_m(Z_2) = - I_m(Z_{out})$$

To make FM oscillator working at the optimum state, Z_R' and Z_2 must be selected rationally. The determination of Z_2 depends on the designing sizes l_2 and l_3 of the output match network.

5. The design example, experiment result and analysis

We now design a FM oscillator stabilized with DR, which operats at 2110MHZ. First, the dielectic resonator A_{6-5} is selected, its dielectric constant $\varepsilon_r = 38$, the temperature coefficient $\tau_f =$ 0ppm/ ℃ . With the calculating results in the chapter three, the sizes of this dielectric resonator are Φ26mm/L16.7mm. In accordance with known S parameters of the transistor and the design principle in the chapter four, the circuit sizes of FM oscillator are calculated out

$$l_1 = 37.2\text{mm} \quad l_2 = 7.8\text{mm} \quad l_3 = 4.2\text{mm}$$

The entire FM oscillator is made on a ceramic substrate (the dielecric constant $\varepsilon_{r1} = 9.6$), which sizes are $60 \times 50 \times 1\text{mm}^3$. After adjusting it properly, targets can be obtained as follows

(1) The central operating frequency $f_0 = 2110$MHz.

(2) The output power is greater than 24mW.

(3) The frequency stable-degree $\Delta f/f_0 < 3\times10^{-4}$ (-10~ +45℃).

(4) The modulating characteristic

The modulating frequency deviatons of the FM oscillator varing with the ranges of the modulatimg signal are shown in Figure 5.

Through experiment results mentioned above, we can see that this FM oscillator has the positive temperature feature. As we have known, its temperature feature not only depends on DR, but also the transistor and DR coupling with microstrip line. For this reason, to increase futher the frequeency stable-degree, the steps may be taken as follows

a. The positive temperature feature of the circuit structure and the transistor can be compensated with DR having the negative temperature feature.

b. Selecting medium- power transistor, the output power can be increased so that DR coupling with the microstrip line is decreased, then the stable-degree of FM oscillator will be also increased further.

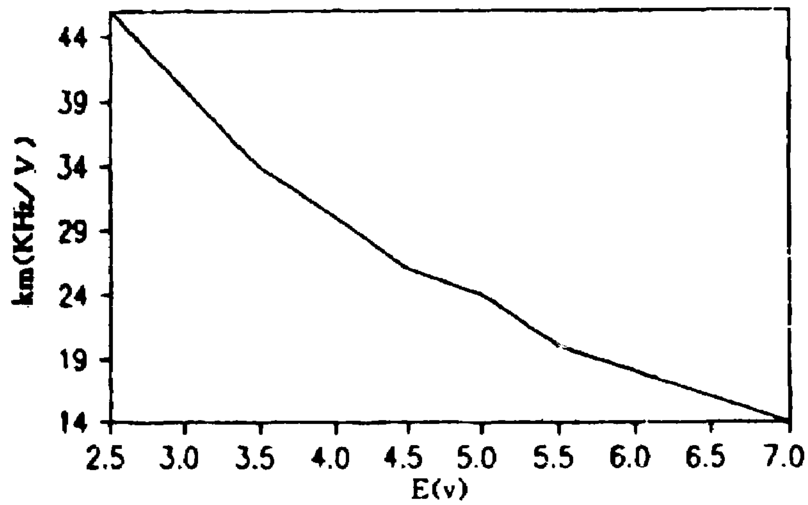


Fig. 5 Modulating freqency deviations varing with the ranges of the modulating signal

6. Conclusion

Appling the dielectric resonator technique and the FM oscillator theory, this paper has researched into FM oscillator stabilized with DR in the S-band. Because it is of simple circuit, small size, light weight and low cost, there will be a certain superiority if it is used in the airbone telemetry transmitter. So, this job has practical significance. In the practice, how to select DR with proper temperature coefficient and the medium-power transistor, so that the frequency stable-degree can be is raised to 10^{-6} grade, further research jobs will be done.

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