DIELECTRIC SPLIT-RING RESONATORS AND THEIR APPLICATION TO FILTERS AND OSCILLATORS

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ABSTRACT

Dielectric split-ring resonators (DSRs) having excellent properties, such as small size, low loss and good temperature stability, have been developed.

The experimental studies carried out to obtain design charts for applications, and the trial filters and oscillators fabricated, have shown that the DSRs have many attractive features above the UHF band.

INTRODUCTION

The miniaturization of radio equipment has been in progress with development of microwave communication systems and broadcasting systems. This technological trend requires compact and low loss resonators.

For this requirement, microstrip half wave-length open-ring resonators [1), 2)] have attractive features above the X band.

To make these resonators more small in the UHF band, the authors previously proposed microstrip-line split-ring resonators and reported their application to varactor tuned bandpass filters.[3)]

We have recently developed the dielectric split-ring resonators (DSRs) to realize more compact and lower loss resonators. This paper describes the properties of DSRs using low loss, high dielectric constant ceramics and their application to bandpass filters and fixed frequency oscillators with good temperature stability.

The advantages of the DSR are its ability to provide good resonance charactisistics such as compact size, low loss, and high temperature stability.

Therefore, DSRs can be utilized in small-sized filters and stable oscillators for radio equipment above the UHF band.

STRUCTURE OF THE DSR

Fig. 1 shows the structure of the newly developed DSR. It is composed of ring-shaped ceramics with metallized film and tuning capacitor which connects to both ends of a resonator conductor.

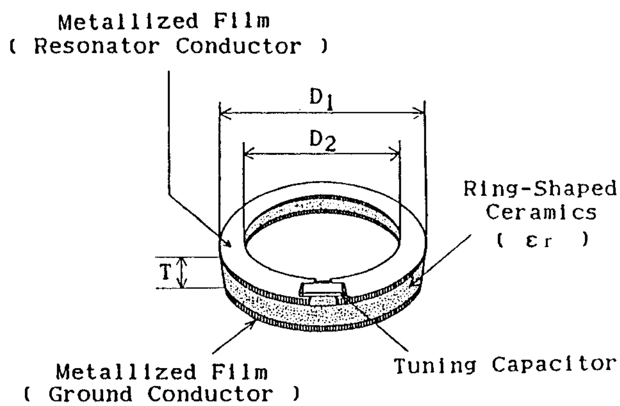

Fig. 1 Structure of the DSR

The use of low loss, high dielectric constant ceramics and the new structure have made miniaturization possible without losing the advantages of the conventional one wave-length ring resonator, which is characterized by no RF short circuited points and less radiation loss.

The dominant resonance mode is TEM. The resonance frequency can be calculated from the electric parameters of the resonator, such as the resonator length, characteristic impedance and tuning capacitance, the same as for the microstrip-line split-ring resonator.[3)]

The advantages of the DSR are as follows.

1) excellent resonance characteristics such as compact size, low loss and good temperature stability, compared with conventional TEM mode resonators
2) simple configuration of coupling circuits
3) tunable to a wide range of frequencies
4) easily mounted on a printed circuit board

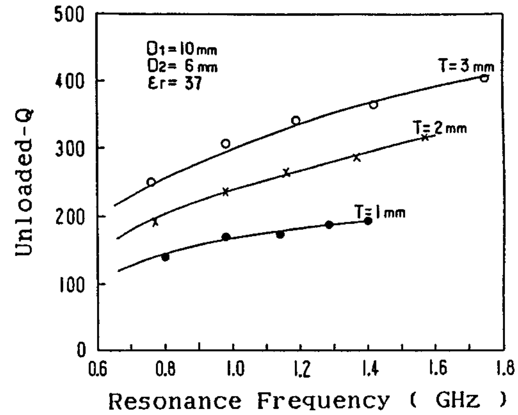

Fig. 3 Unloaded Q of the DSR

FUNDAMENTAL PROPERITES OF THE DSR

The relationship between resonance frequency and tuning capacitance is shown in Fig. 2. The results show that the resonance frequency can be tuned over a range exceeding one octave by a tuning capacitor without changing the resonator structure.

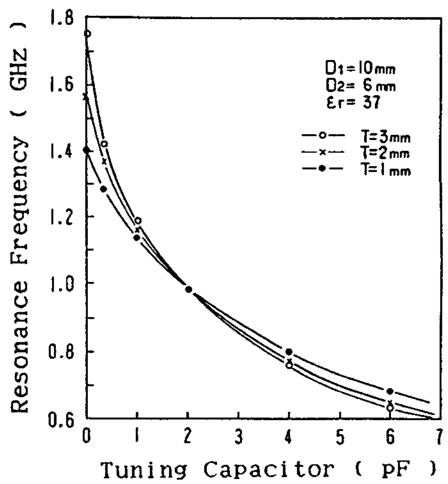

Fig. 2 Resonance properties of the DSR

Fig. 3 shows the measured unloaded-Q of the DSR. As the unloaded-Q of the DSR is primarily affected by the dissipation factor of the tuning capacitor, it is preferable to use a parallel plate capacitor with a low dissipation factor.

In the application of the DSR to filters and oscillators, it is necessary to obtain the external coupling factor (Qex: external Q) and interstage coupling factor (k).

Fig. 4 show the measured Qex by tapping, which is a case of magnetic coupling.

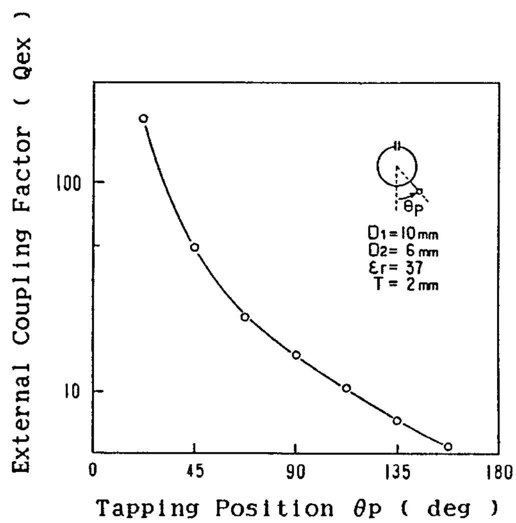

Fig. 4 External coupling factor (Qex)

The interstage coupling measured by the resonator pair is shown in Fig. 5. These results indicate that it is suitable for bandpass filters within a several percent bandwidth, because it is diffucult to realize a tight coupling by structural restriction.

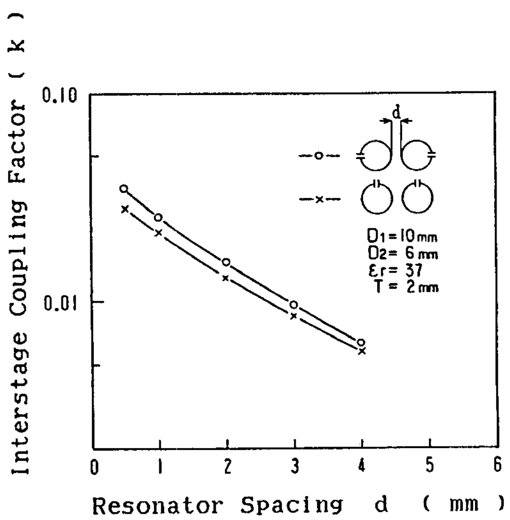

Fig. 5 Interstage coupling factor (k)

APPLICATION TO FILTERS AND OSCILLATORS

On the basis of the points discussed above, an experimental bandpass filter and an oscillator were designed.

The design parameters of the bandpass filter are as follows:

Center frequency	fc = 1 GHz
Relative bandwidth	w = 2%
Number of resonators	N = 2

The bandpass filter was fabricated with the DSRs having a dielectric constant of $\varepsilon_r = 37$ and a thickness of 2 mm.

The photograph and the measured response of the experimental bandpass filter are shown in Fig. 6 and Fig. 7 respectively.

The insertion losses of the experimental bandpass fileter are less than 2 dB. As shown from these results, the responses have two attenuation points in the stopband, similar to a conventional elliptic function filter.

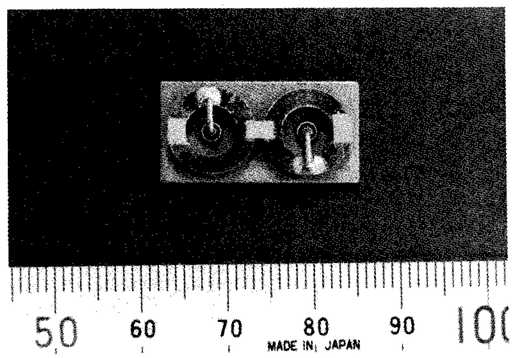

Fig. 6 Photograph of the experimental bandpass filter

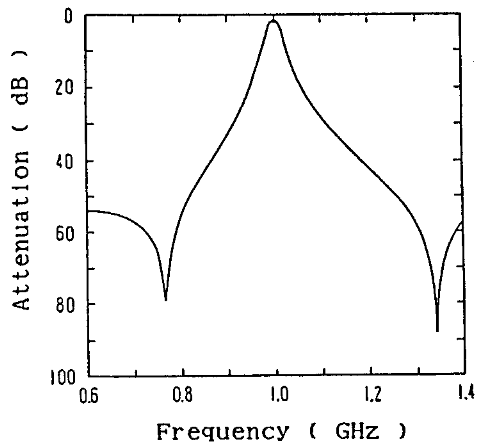

Fig. 7 Measured response of the experimental bandpass filter

Fig. 8 and Fig. 9 show the photograph and the circuit of the experimental fixed frequency oscillator respectively. This oscillator consists of a Colpitts type circuit with a commom-collector configuration.

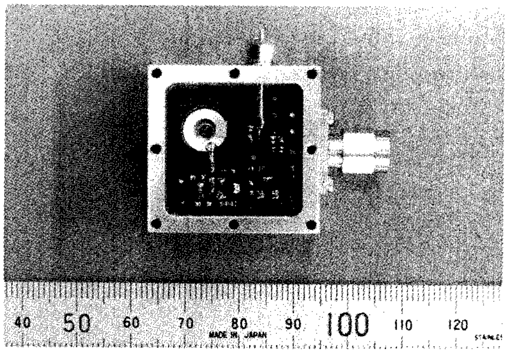

Fig. 8 Photograph of the experimental oscillator

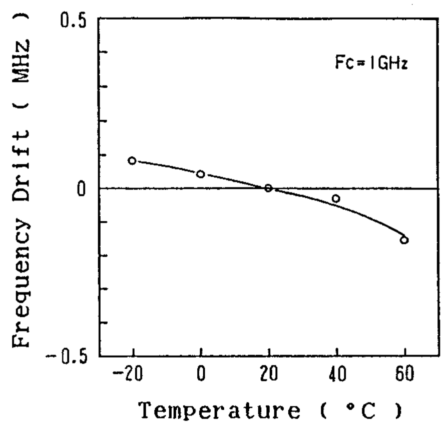

Fig. 10 Measured temperature stability of the experimental oscillator

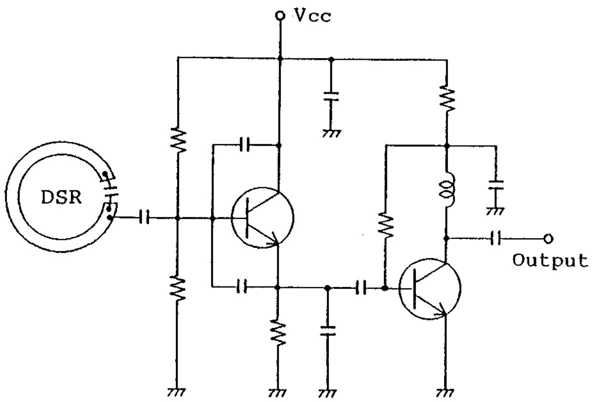

Fig. 9 Circuit diagram of the experimental oscillator

The output power is about 0 dBm, and the center frequency is close to 1 GHz. The SSB phase noise at 10 kHz offset from the carrier is approximately −118 dBc/Hz. The characteristics of the frequency drift as measured against temperature are shown in Fig. 10.

These results indicate that the frequncy drift is within 300 kHz over a wide range (−20 ~ 60 °C).

These performances are superior to those of the oscillators using a conventional microstrip-line resonator.

CONCLUSIONS

The dielectric split-ring resonator (DSR) has been developed and its properties measured. Besides, its applications to bandpass filters and fixed frequency oscillators have been demonstrated.

The experimental bandpass filters and fixed frequency oscillators showed excellent performances, as expected.

ACKNOWLEDGEMENT

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