United States Patent

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[15] 3,703,689

[45] Nov. 21, 1972

[54] **MICROWAVE VARACTOR-TUNED RESONATOR FOR PRESELECTOR**

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[73] Assignee: **Microdyne Corporation**

[22] Filed: **Feb. 26, 1971**

[21] Appl. No.: **119,178**

[52] **U.S. Cl.**.....**333/82 B**, 333/73 R, 333/83 R, 334/45

[51] **Int. Cl.**.....**H01p 7/04**

[58] **Field of Search** .....333/83 R, 82 R, 82 B, 73 R, 333/73 W, 76; 334/45, 15

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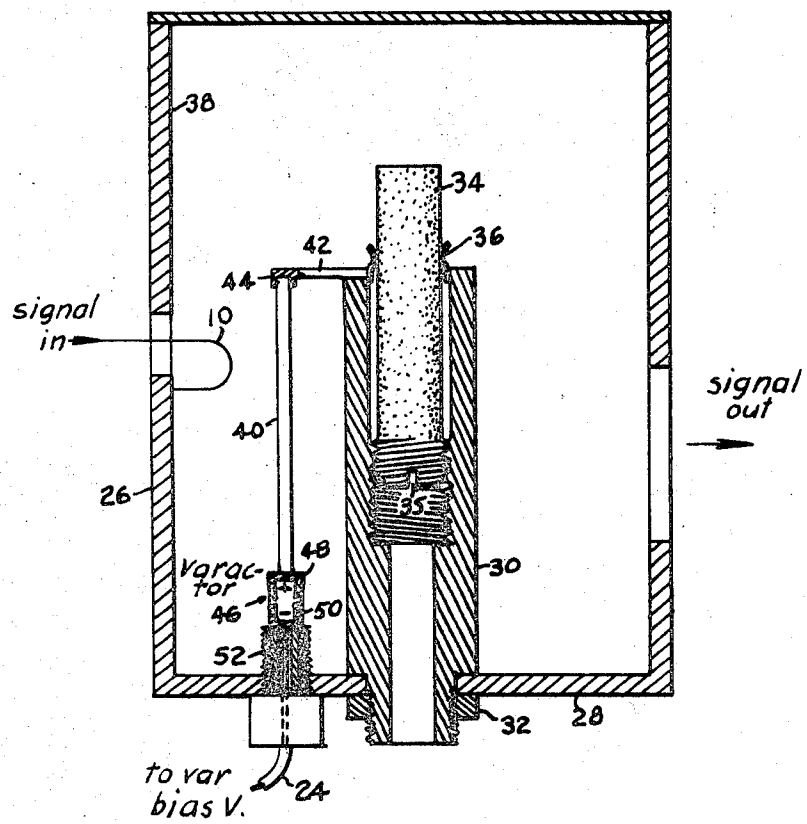
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[57] **ABSTRACT**

A tunable varactor resonator has a high-Q cavity and a concentric inner probe, with one end of the concentric probe connected electrically to an eccentric probe of higher characteristic impedance in series with a varactor. Minimum insertion loss, approximately constant unloaded Q, and usability of low-Q varactor diodes are features.

1 Claim, 3 Drawing Figures



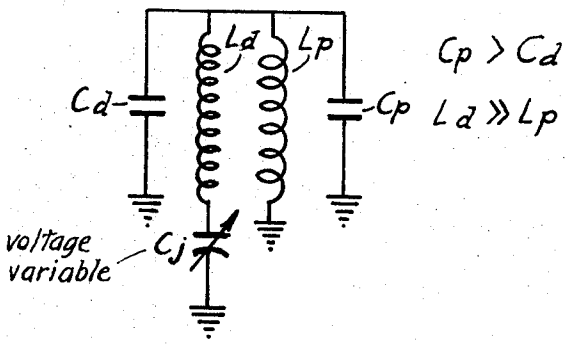


FIG. 1.

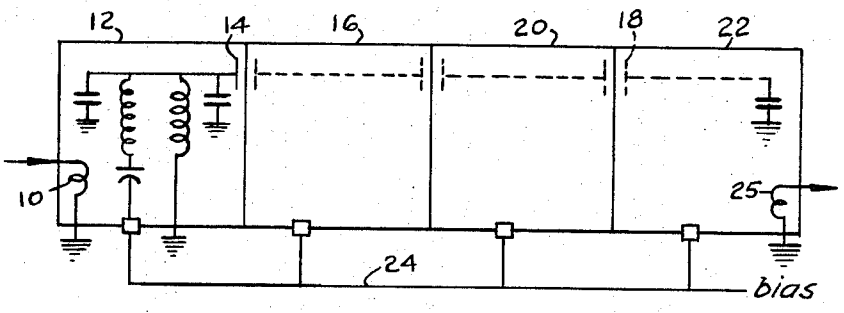


FIG. 2.

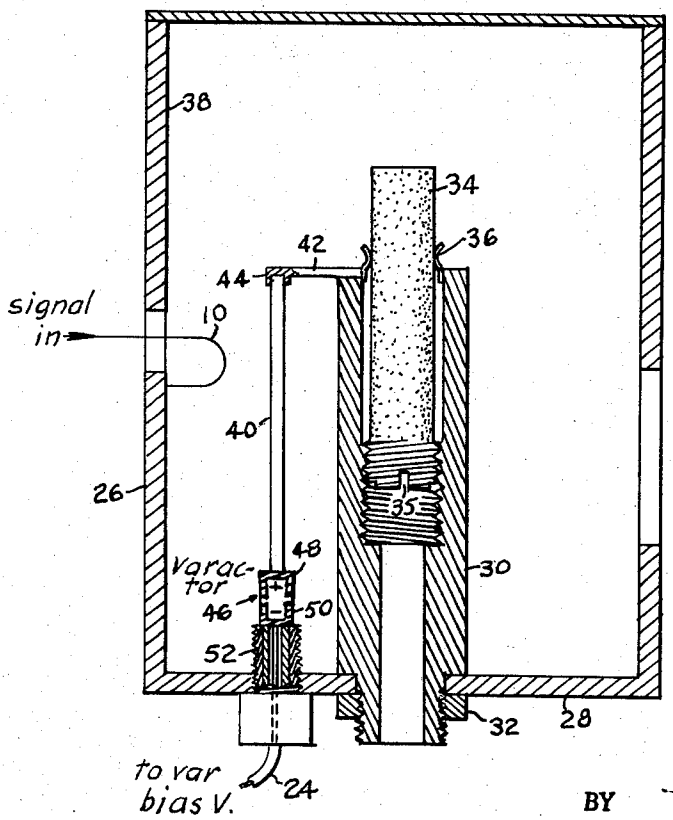


FIG. 3.

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MICROWAVE VARACTOR-TUNED RESONATOR FOR PRESELECTOR

BACKGROUND OF THE INVENTION

In the design of highly selective ultra-high-frequency radio receivers, it is common practice to subject incoming signals to a succession of mixing or heterodyning operations, but it is known also that it is advantageous to provide a non-amplifying preselector between the antenna and the first mixer stage, or any straight radio-frequency amplifier. Interfering or spurious inputs are thus reduced or eliminated with little attenuation of the incoming power, and the sought-for signal can be amplified to higher levels then when it is relatively impure. In addition, the preselector minimizes the radiation of receiver-generated signals.

For use at ultra-high-frequencies, it is necessary for the preselector (which is essentially a highly selective filter, or more usually, a series of filter sections) to present the high Q characteristic of all sharply tuned devices. Some provision must also be made for tuning adjustments to permit a reasonable range of frequencies to be covered. In prior art preselectors, this adjustment has usually been accomplished by mechanical adjustment of transmission line length associated with the other components of the filter. The moving parts of this type of cavity lead to the possibility of mechanical wear, resulting noise and failure to track accurately, and other defects, such as bulk and the shape factors which are inimical to reasonable values of the circuit Q's.

While it might appear obvious that some of these disadvantages could be overcome by using the variable-capacity property of varactors, the fact is that for use at microwave frequencies, the inherent Q's are then altogether too low to permit the selectivity desired. The present invention provides an arrangement in which a readily available low-Q varactor diode component is combined with high-Q components in a resonant cavity so that an adequate control of the resonance (selective) frequency is achieved, while the effect of the diode on degrading the overall Q is minimized.

SUMMARY OF THE INVENTION

Basically, the end object of the invention is to provide electronic tuning of a microwave resonator having a relatively low insertion loss or attenuation, such as not over 1 db, with a loaded Q in excess of 100, which is relatively uniform over the band. The signal frequency may be, for example, as high as 4 GHz or higher. Two circuits are involved; one of these is the widely known quarter-wave TEM cavity, the other, which is inductively coupled to the same cavity, consists of a length of transmission line that is loaded with the variable capacitance diode, or varactor. This transmission line, with the diode at maximum reverse bias (minimum capacitance), is self-resonant below the operating frequency of the cavity; therefore, minimum capacitance in this circuit will be reflected to the cavity as a minimum value of inductance and will therefore represent the condition of maximum frequency. At minimum reverse bias (maximum capacity) the inductive component reflected to the cavity is maximum, and will correspond to the condition of minimum frequency.

The total inductive reactance thus coupled to the cavity is very high compared to the inductive component of the TEM cavity; therefore the Q of the coupled reactance represents a relatively small degradation in the total Q of the resonator.

Stated differently, at minimum capacitance the effect on the cavity will be maximum because the inductive component reflected is minimum. However, at minimum capacitance the Q of the diode is at its highest. At the condition of maximum capacity the inductive component is maximum and has a minimum effect on the cavity. It can therefore be seen that due to the offsetting effects, the unloaded Q of the cavity may be kept essentially constant across the frequency band of interest. In still other words, the point of minimum Q of the diode occurs at the point of minimum loading of the cavity. The point of maximum Q of the diode occurs at the point of maximum loading of the cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of one stage of a preselector (less input and output coupling) denoting the basic resonator arrangement.

FIG. 2 is a similar diagram of a four-stage pre-selector showing iris coupling between stages and one form of input and output coupling to and from the first and last stages.

FIG. 3 is a vertical sectional view of a varactor-tuned pre-selector stage incorporating the present invention, and suitable for microwave frequencies.

DETAILED DESCRIPTION

GENERAL

Lp and Cp of FIG. 1 illustrates the equivalent circuit of a conventional resonator design as employed in the art, and described in texts, such as "Microwave Filters, Impedance Matching Networks and Coupling Structures" by Matthaei et al. McGraw-Hill (1964). For tuning to a precise frequency in the microwave region, a varactor (voltage-variable capacitor) Cj can be connected in series with inductance Ld, and varied by adjusting the value of reverse-bias voltage applied to its control lead. However, such a device would be very inefficient, due to the very large attenuation (insertion loss) in each stage of the preselector, in turn due to the inherently low Q of the diode Cj.

The problem encountered at microwave frequencies is utilizing readily available low Q variable capacitance diodes in such a way as not to degrade the Q of the resonator below the point of being usable in a microwave filter. The pre-selector in its simplest form consists of: (1) a quarter-wave resonator that is tuned to the desired operating frequency, (*fo*); (2) the varactor diode (Cj) with its associated line, resonant at a lower frequency *f*1. The frequency of the preselector is determined by: (1) the length of the concentric center conductor, (LpCp), and (2) the resonant frequency of the eccentric line (LdCd) and the diode capacitance (Cj). The tuning range and the unloaded Q of the cavity are dependent upon the ratio of the two resonant frequencies. The greater the ratio of the frequencies the smaller the tuning range. The smaller the tuning range the higher the unloaded Q. Basically, the technique employed at microwave frequencies is to

tune a high Q resonant cavity (LpCp) with a lightly coupled low Q circuit, (LdCd) containing the variable capacitance diode (Cj). The low Q resonant circuit, by itself, is self-resonant below the operating frequency of the cavity so that at the cavity frequency it appears as an inductive reactance. Electronic tuning of the device is accomplished by changing the resonant frequency of LdCd, which in turn changes the resonant frequency of LpCp. The end object of this device is to provide electronic tuning of a microwave resonator having a relatively low insertion loss, 1 db or less, with loaded Q's in excess of 100.

Basically, the resonator consists of two circuits. One circuit is the widely known quarter-wave TEM mode cavity. The other circuit, which is inductively coupled to the TEM cavity, consists of a length of transmission line that is loaded with a variable capacitance diode. The transmission line, with the diode at maximum reverse bias (minimum capacitance), is self-resonant below the operating frequency of the cavity; therefore, minimum capacitance in this circuit will be reflected to the cavity as a minimum inductance and will therefore represent the condition of f-maximum. At minimum bias (maximum capacity) the inductive component reflected to the cavity is maximum and will represent the condition of *f*-minimum.

The total inductive reactance coupled to the cavity is very high compared to the inductive component of the TEM cavity; therefore the Q of the coupled reactance represents a relatively small degradation in the total Q of the resonator.

At minimum capacitance the effect on the cavity will be maximum because the inductive component reflected is minimum. However, at minimum capacitance the Q of the diode is highest. At the condition of maximum capacity the inductive component is maximum and has a minimum effect on the cavity. It can therefore be seen that due to the offsetting effects, the unloaded Q of the cavity is relatively constant across the band of interest. In other words, the point of minimum Q of the diode occurs at the point of minimum loading of the cavity. The point of maximum Q of the diode occurs at the point of maximum loading of the cavity.

FIG. 2 illustrates in diagram form a four-stage resonator with input coupling loop 10, for example, feeding the incoming signal to the first-stage can 12, and after filtering exiting at 14 by capacitor coupling to the second stage can 16, thence by similar coupling to the third stage can 20, and similarly at 18 into the fourth stage can 22. The respective tuning varactors are controlled over a common reverse-bias line 24 from outside the body of the pre-selector, with provision for individual trimming of these biases for alignment purposes. The output signal from the fourth stage 22 is taken by means of coupling loop 25.

DETAILS OF THE RESONATOR OF THE INVENTION

The construction of the individual stages, as physically embodied, is typically shown by FIG. 3, illustrating the details of first stage 12. The "can" referred to above constitutes the outer conductor of the quarter-wave cavity, and is a metal cylinder 26 which is closed at the top, and at the bottom by the mounting plate 28. Into this plate the metal stub 30 is secured, as by a threaded nut 32. Since the effective length of the central conductor within the cavity 26 tunes the cavity, provision is made for closely adjusting its length by an external screwdriver-like blade (not shown) inserted in the slot 35 whereby to rotate the metal probe 34 and make more or less of it project above the top of the stub. Spring fingers 36 of beryllium copper or the like have a good running fit over the body of the probe 34, and are soldered to the end of the stub 30.

The stub-probe combination is the centered element within the can of the concentric line, where mounting plate 28 performs the "shorting" function. The length of the line is adjusted to be greater than one-fourth wavelength at the operating frequency, for reasons explained above. Actually, it is the inside surface 38 of can 26 which functions as the outer conductor of the concentric line. The ratio of the inside diameter of the cavity 26 (at 38) to the outer diameter of the center conductor is chosen for optimum (high) Q.

Within the annular space surrounding the probe 34 is mounted the second major component of the resonator, a length of transmission line 40 extending parallel to the axis of the cavity 26. Such lines have much higher characteristic impedance than do concentric lines such as just described, yet by positioning it in this way, i.e., the fact that it is within the cavity, its effect as a mere lossy (low-Q) body on the cavity itself is minimized. The length of this line is made such that, with the added capacitance of the varactor diode, the resonance is below the operating frequency of the resonator, and the distance of its upper end from the stub 30 is fixed by the length of a small metal tab 42 soldered to the top of stub 34 and electrically and mechanically connected to a metal cap on socket 44. This distance controls the amount of coupling between the cavity and the line 40. At the lower end, the "eccentric" line is held mechanically by mounting the varactor diode 46 between two caps in the usual way, the upper metal cap 48 for the anode being soldered to the lower end of line 40 and the lower cap 50 being mounted on a feed-through element 52 of known type which passes the control conductor 24 from the varactor cathode through the mounting plate 28 to the inverse bias source. The feed-through also secures the lower end of line 40 in position, and provides an r-f ground at the cathode of the varactor.

What is claimed is:

1. An electronically tuned resonator comprising a microwave resonator cavity element, a conductive probe concentrically positioned in said cavity element and forming therewith a high-Q shorted line resonating at somewhat higher frequency than that desired for operation, a conductive element eccentrically positioned in said cavity element and connected at one end to a point on said probe at an elevated RF potential, and a varactor diode in said cavity in series between the other end of said conductive element and a point on said probe of low RF potential; said conductive element forming with said cavity element a second shorted line resonating at a somewhat lower frequency than that desired for operation, and having a relatively lower Q, and a source of adjustable bias voltage connected to the varactor diode for adjusting the effective frequency of said resonator.

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