RESONATOR AND PRESELECTOR IN BALANCED STRIP LINE

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Introduction

One of Raytheon's commercial applications involves microwave circuitry in balanced strip line, with a 3/8" spacing between ground planes. Though the less critical parts of the unit are etched in copper-clad Teflon-Fibreglas, two of the components are of higher Q than can reliably be obtained in the presence of plastic. They are:

1. a resonator, for use as a frequency stabilizing reference element in an AFC circuit; and
2. a four-stage maximally flat preselector filter.

These units are made of separate strips of metal, and do not depend on the plastic sheet for their support.

The unit is intended to operate over a 4 1/2% band centered on 6725 mc, and was designed to avoid expensive parts and assemblies.

The design requirements were for a resonator with an unloaded Q of 1980, and with no more than $\pm$ 0.45 mc frequency variation over operational extremes of temperature and humidity; and for a preselector with less than 3.5 db. loss and a 30 mc pass band. Both units satisfy the overall electrical and mechanical design without requiring special high-cost structures. In fact, the microwave head is, in balanced strip line, about half as expensive as in conventional plumbing. In addition, the present cost will be further reduced as larger quantities are considered.

Reference Resonator

Previous work on strip line resonators at Raytheon involved a short, open-ended section of line, consisting of a thin copper strip one or one-and-a-half wavelengths long supported at two voltage minima by polystyrene slats (see Fig. 1). While, by variations in width, thickness, and length, values of Q from 600 to 3600 were obtained, it was difficult to achieve the proper tuning. Dielectric tuning tended to reduce the Q at the low end of the band; capacity-screw tuning (as restricted by design limitations) was prone to erratic results or to the generation of radiative modes; and distortion of the ground planes did not permit tuning over a wide enough frequency range. Also, no method of mounting the open-end resonator could be found which would prevent frequency drift with temperature over the tuning range. These and other disadvantages eliminated the open-ended type from consideration.

In order to tune by changing the resonator length, end-supported types were chosen. First tests were made on various sizes of 3/4 wavelengths long round rods, screwed firmly into a spacing bar between ground planes. We intended to tune by adjusting the projecting length of a small screw which would run down the center of the resonator and emerge slightly from its free end. Tests showed Q's of 450 or less, and it was concluded that the cylindrical shape tended to concentrate the currents sufficiently, along the lines nearest the ground planes, to give excessive loss.

Flat end-supported strips were then tried. In the first configurations tested, the resonator emerged from a slot in a two-piece split spacing bar between the ground planes (as illustrated in Fig. 2) so that the halves of the spacing bar provided the short circuits from the base of the resonator to the ground planes. Smooth slots, slots with fingers, and choked slots were used, but no values of Q over 1000 were measured. Since we felt the low Q was mostly due to side fringing losses and to losses at the joints between the spacer and the ground planes, we tried to eliminate them by making the resonator short circuits no wider than the resonator itself, and by placing them away from the ground plane spacing bar. With two such narrow clamped blocks, as shown in Fig. 3, average values of Q were near 1250. To ensure positive contact, the blocks had .005" thick ridges at potentially lossy joints, so that the clamping pressure would be concentrated on a very small area. Nevertheless, the arrangement was still very sensitive to the tightness of clamping and to the accuracy of alignment; individual measurements varied from 470 to 2300. With blocks that had quarter-wave-length long fingers (see Fig. 4) results were still erratic, but around a higher average Q of 1600. Use of blocks with half-wave choke traps that had contact fingers (shown in Fig. 5), resulted in lower Q's (around 1300) because of choke losses, but with very stable results, since the arrangement no longer required good contacts or tight clamping.

For manufacturing economy the above doubly-choked blocks were replaced by blocks with single folded half-wave chokes (see Fig. 6), so that only the movable joints between the resonator and the short-circuiting blocks were choked, while the joints between the blocks and the ground plane (which do not require moving during tuning) result from clamping each block to the ground plane with screws. The clamping pressure is, as before, concentrated on a narrow ridge.

In order to provide a lossless short circuit for comparison, a 3/8" wide, 1/32" thick, 3/4 wavelength long resonator was soldered into a slot through the spacing bar between the ground planes, in the same configuration as in Fig. 2. It gave an unloaded Q of 3000.

By increasing the width of the resonator to 1/2" and of its support to 5/8", Q's were brought up to about 1800; by increasing the length of the resonator to 5/4 wavelengths, stable reproducible Q's were consistently maintained around 2100, which is slightly above the equipment design requirements.

Tuning, accomplished by changing the length of the resonator, was originally planned with a differential screw. However, direct screw advance by means of a 4.40 lock nut has proved quite satisfactory and, when backed up by a coil spring, free from backlash. Naturally, the screw advance tuning mechanism can cover far more than a 4 1/2% frequency band; it is limited only by the operational range of the choke.

To eliminate humidity-induced drift, the resonator was surrounded by polyfoam (with a density of 1.4 lb/ft^3). In preliminary tests, humidity variation from zero to 100% @ 55°C caused less than ± 0.25 mc frequency variation. Use of expansion compensation makes the temperature drift much smaller.

The problem of coupling was originally studied by having the coupling line approach the free end of the resonator. It was found that coupling versus gap followed an exponential law, as shown in the graph in Fig. 7. However, it is obvious that end coupling will change in value as the resonator length is changed, leading to the ultimate choice of side coupling (at the 3/4 wavelength point on the resonator) for both input and output. Use of the quarter-wave point would have been somewhat less frequency-sensitive, but was impossible within the design limitations. Unfortunately, it is rather difficult to maintain the sidewise position of the resonator accurately enough to prevent variations in the input and output coupling coefficients. An arrangement which makes the coupling depend less on the physical size of the gap is shown in Fig. 8, where the open space between the end of the coupling line and the resonator is made quite narrow, while another wider space, etched quite accurately on the Teflon-Fibreglas plastic, provides the controlling coupling gap. This is the analogue of a large and a small capacitor connected in series. The total capacitance in such a case is controlled almost wholly by the smaller, so that the larger one can have quite loose tolerances. With this arrangement, couplings can be maintained within the desired tolerances over a wide range of misalignment.

Preselector

Four high-Q resonators, synchronously tuned and properly coupled together, form the preselector - a four stage maximally flat band-pass filter. The half-power bandwidth is about 30 mc and the insertion loss at resonance must be less than 3.5 db.

The preselector, unlike the reference resonator, is broad enough to tolerate the frequency drift resulting from temperature and humidity variations, so no method of reducing drift was considered. Three different configurations were investigated:

1. The so-called in-line filter with elements an integral number of half wave-lengths long, made up of a line of the elements shown in Fig. 1.
2. End-supported resonators, as used in the reference cavity, an odd number of quarter wavelengths long.
3. An in-line construction made of continuous line, where the resonators would be formed between discontinuities, such as posts or sudden projections or constrictions in the line width, and coupled by quarter-wavelength coupling sections. This arrangement is analogous to waveguide quarter-wave coupled filters formed by post or iris discontinuities.

The in-line filter with dielectric tuning was selected, because it seemed to offer the best possibilities of obtaining high unloaded Q's and was easily adapted to the packaging problems at hand. The end-supported resonator filter had originally seemed more promising for tuning considerations, as tuning could be accomplished by changing the lengths (as in the reference resonator). However, in the case of the filter, all four stages have to be tuned to the same frequency. This could be done by tuning each stage separately, involving prohibitive tolerance and alignment problems. Alternatively, all stages could be attached together like a letter "E" (but with four bars), and tuned as a unit, and each stage provided with a trimmer for fine adjustment. Packaging considerations made difficult the inclusion of the type of trimmer that would not interfere with coupling. Furthermore, this arrangement would be costly as, in effect, two separate tuning structures were required.

The quarter-wave coupled filter affords more freedom in supporting the center conductor structure. However, for equal performance with the in-line filter, the quarter-wave coupled filter is slightly longer and thus more unwieldy. On that basis it was rejected for our purposes. It may, however, be preferable in cases where bandwidth is critical, as it minimizes the coupling tolerance problem and gives more freedom for mounting the tuning structures.

The final layout of the filters is as shown in Fig. 9. Resonators one wavelength long are used; this length provides a higher unloaded Q and a simpler support problem than half-wavelength resonators. Though early tests had shown an increase of about 10% in Q for still longer resonators, it was felt that this did not justify the further increase in length. The resonators are supported at the high current, low voltage points 1/4 wavelength from each end of the resonator by polystyrene slats. A slight cut-back in the width of the resonator ensures its positive positioning. Because of the finite thickness of the polystyrene supports as well as the shift (with frequency tuning) in the position of the nodal points, it is obviously impossible to restrict the supports entirely to the low-voltage points. Hence some degradation of the unloaded Q by losses in the polystyrene is inevitable. While no exact numerical measurements of the lowering of the unloaded Q by the supports were taken, the supports were positioned so as to give least loss at the lower part of the band; in this way the increased losses at the lower frequencies due to dielectric tuning are partially offset.

The width of the preselector between the ground plane spacing bars was originally made small in order to suppress radiation due to tilt in the resonators. Erratic results were observed, and were attributed to poor contact between the spacer bars and the ground plane. When the width increased to 2 inches (removing these joints from the more concentrated field), measurements gave more consistent results.

Dielectric tuning at the center of the resonator was chosen. Though the losses introduced by the plastic are a serious problem, it was felt that it could be tolerated and that dielectric tuning was a cheaper method and one that eliminated all problems of making good contact between sliding metal parts. The final tuner is shown in Fig. 10. It consists of a Teflon cylinder mounted eccentrically on a Fibreglas shaft. The cylinder is slotted so that it passes over the resonator. Originally, Rexolite was used as the tuner material, on a phenolic shaft. By switching to Teflon, a slight improvement in Q was obtained. A further improvement resulted when the phenolic shaft was positioned as far away from the resonator as possible while still obtaining the desired tuning range.

Typical band-pass characteristic curves are shown in Fig. 11 for the high and low-frequency ends of the tuning range. The respective values of unloaded Q are 2600 and 1700, as calculated from the insertion loss. Later design modifications have improved the unloaded Q to about 3000 at the high-frequency end and about 1900 at the low-frequency end of the band.

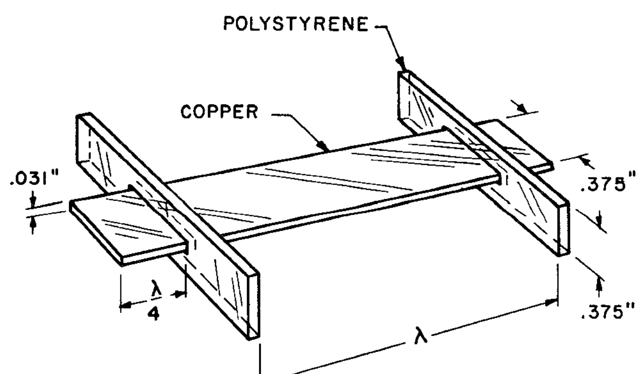

Fig. 1 - Early resonator design.

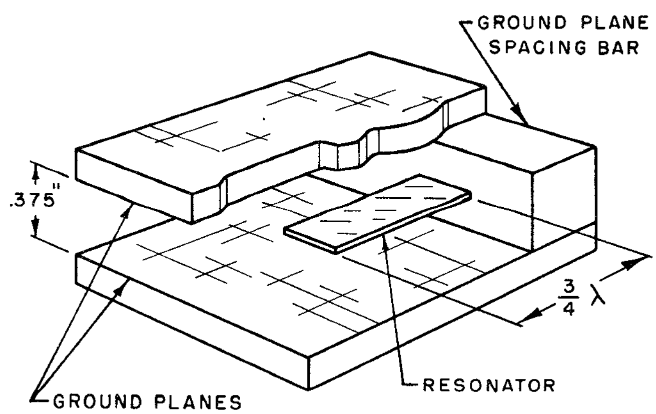

Fig. 2 - "Standard" end-mounted resonator.

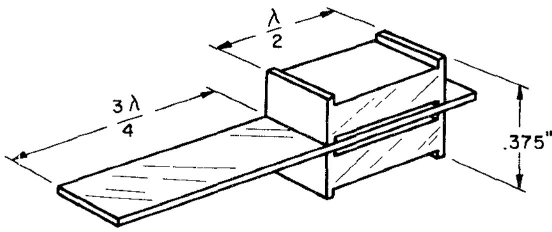

Fig. 3 - Half-wave clamp.

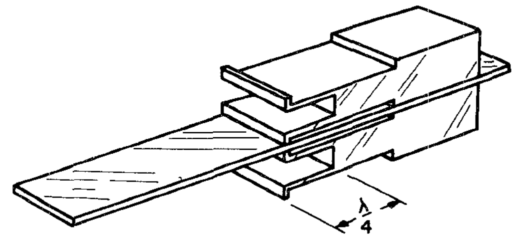

Fig. 4 - Quarter-wave fingers.

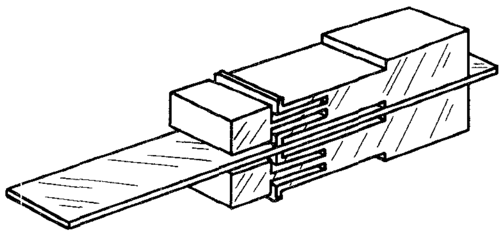

Fig. 5 - Choke with contact fingers.

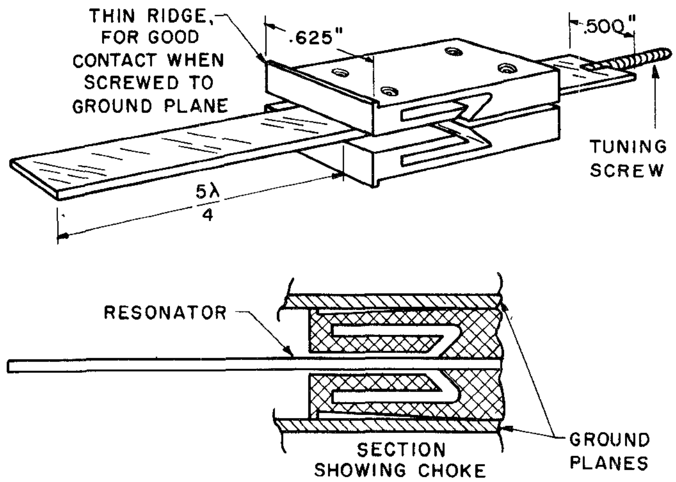

Fig. 6 - Fingerless choke.

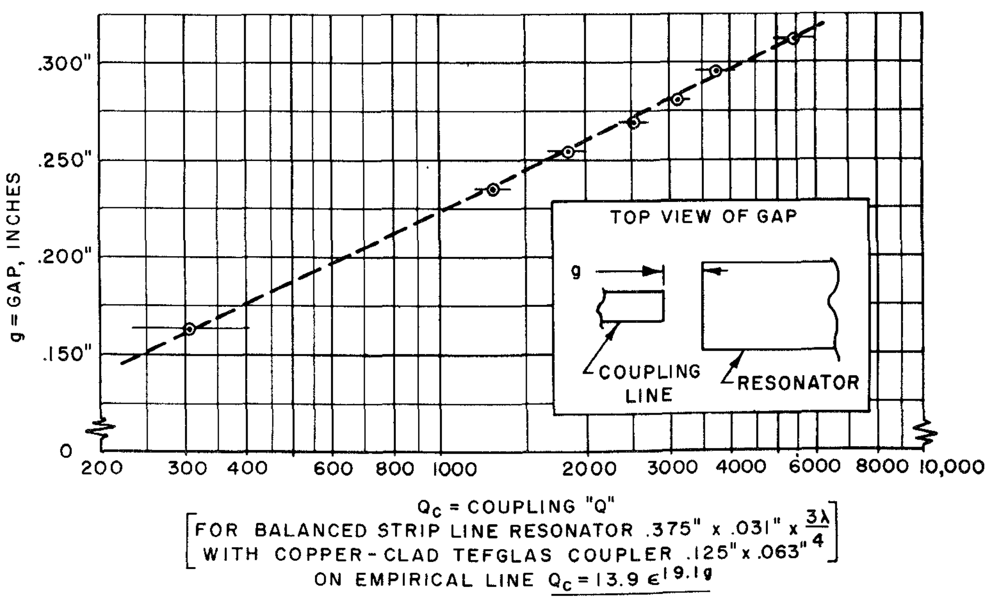

Fig. 7 - Coupling versus gap size.

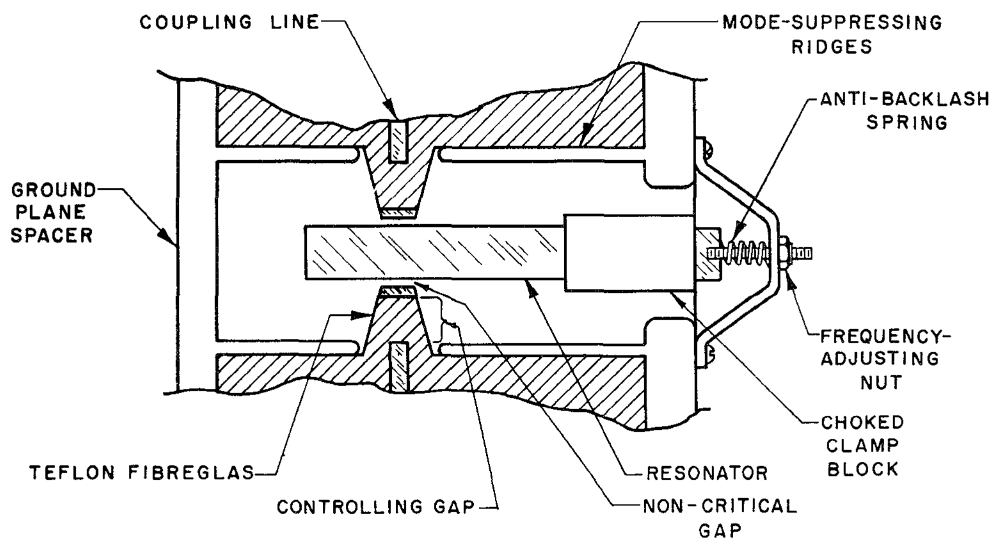

Fig. 8 - Coupling to resonator (top view with upper ground plane removed).

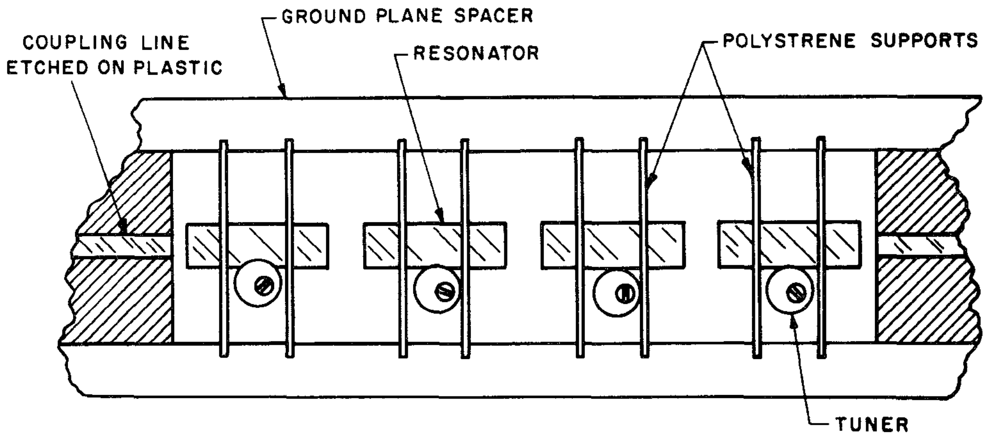

Fig. 9 - Top view of in-line filter (top ground plane removed).

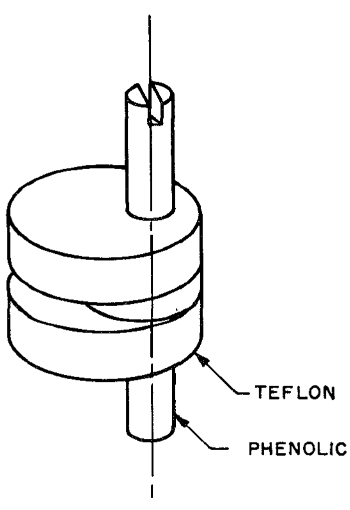

Fig. 10 - Dielectric tuning element.

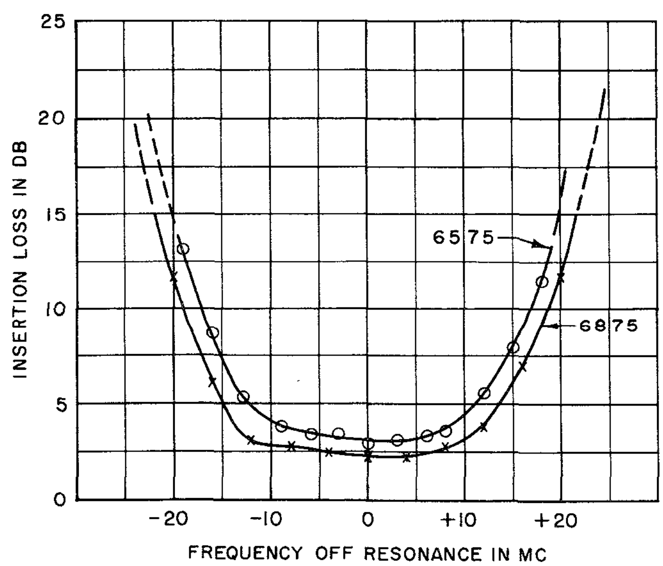

Fig. 11 - Bandpass characteristics of preselector.