# RESONANT CAVITIES FOR DUPLEX FILTERS IN VHF REPEATERS: ANALISYS, IMPLEMENTATION, AND TESTING

Gheorghe SAUCIUC
*Tehnical University "Gheorghe Asachi" of Iasi - Faculty of Electronics, Telecommunication and Information Tehnology, Bd. Carol I, no. 11, Iaşi, 700506; tel 0746 199741 and Fax 0232 217720, sauciucgheorghe@yahoo.com*

**Abstract: In this paper I presented the role of filters duplex in structure of voice repetors, operating principles specific subassembly transmission and subassembly reception. I wanted to do a filter, for building a repeater duplexer for band 144Mhz - 146Mhz. I described how to make a cavity. Leaving the wiring diagram and I checked, depending on the size, if designed cavity can be used for VHF frequencies corresponding. I examined the response of this filter, for receiving and transmitting frequencies, specific to repetor that will be made.**

***Keywords:*** *repeater,* band pass filters (BPF), band rejection filters (BRF), resonant cavity, attenuation.

## I. DUPLEXER FILTERS

A typical duplexer filter [1] for a repeater - Fig.1 is a unit consisting of two filters:

- one that allows the signal from the antenna to reach the receiver input, while rejecting it from the path towards the transmitter output, and
- one that allows the signal from the transmitter output to reach the antenna, while rejecting it from the path towards the receiver input.

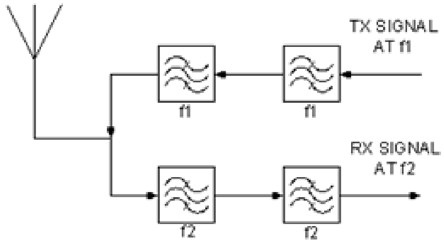


*Figure 1. Block diagram of a duplexer filter*

A filter may include two or more resonant cavities. It should present a good sensitivity and an excellent selectivity in order to adequately separate the two repeater signal paths.

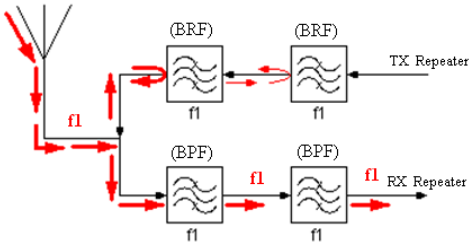


*Figure 2. Signal transmission through the duplexer filter for the repeater receiving mode*

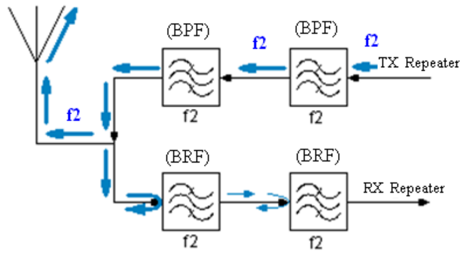


*Figure 3. Signal transmission through the duplexer filter for the repeater transmitting mode*

The signal yielded by the transmitter is supplied smoothly into antenna and it is rejected form the path towards the repeater receiving input. Also, the signal from the antenna is supplied to the repeater receiver input and it is rejected from the path towards the repeater transmitter output. This way the repeater transmitter and receiver do not disturb each other.

## II. DESIGN HYPOTESES

Using a single resonant cavity would induce an attenuation for the unwanted frequency of about 25 dB, which is not enough for a typical repeater implementation. So, a duplexer filter should contain at least two resonant cavities for the reception and two for the transmission in order to obtain high selectivity and acceptable operation.

Figure 4 shows a typical response for a duplexer filter in the VHF band. The two resonant cavities on each path should behave as band pass filter (BPF) for the desired frequency and as band stop (rejection) filter(BRF) for the unwanted frequency.

*Manuscript received May 31, 2012; revised July 17, 2012*

The duplexer filter was designed for the frequency band **144 – 147 MHz** and then adjusted to comply with R7 repeater requirements as specified by ANCOM.

For the cavities on the receiving path the blue curve in Fig. 4 is taken as reference; it has gain of + 0.2 dB for the receiving frequency and an attenuation of 50 dB for the transmitting frequency. For the cavities on the transmitting part the red curve in Fig.4 is taken as reference; it has a gain of + 0.2 dB for transmitting frequency and an attenuation of 50 dB for the receiving frequency.

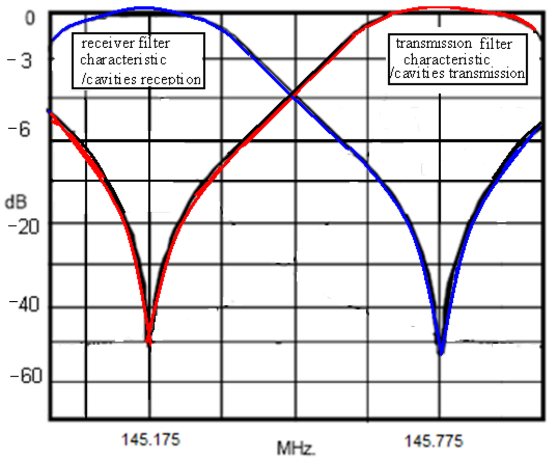


*Figure 4. Reference curves for the cavities' transfer function*

## III. THE PRACTICAL REALISATION OF THE RESONANT CAVITY

The implemented resonant cavity has a configuration as in figure 5 [2]; its electrical equivalence is presented in figure 6.

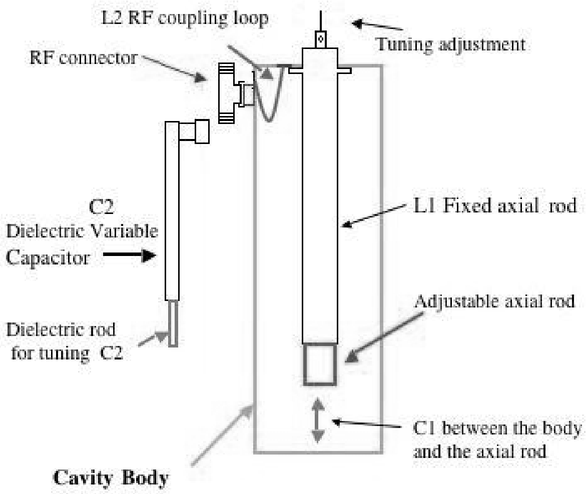


*Figure 5. The resonant cavity configuration*

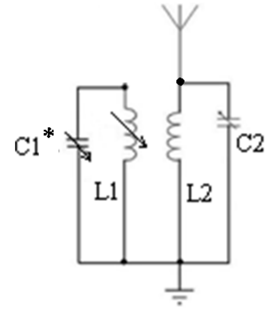


*Figure 6. Electrical equivalence of the resonant cavity*

Assimilating the cavity with a coaxial air, its characteristic impedance could be expressed as $\frac{\eta}{2\pi}\ln(b/a)$ , where *b* is the radius of outer conductor, *a* – is the radius of the inner conductor, and η is the intrinsic impedance of free air space (about 377 ohms). The linear inductance is $L_0 = (\mu/2\pi)ln(b/a)$ and the linear capacity is $C_0 = 2\pi\varepsilon / ln(b/a)$.

External cavity has the dimensions illustrated in Figure 7 [3].

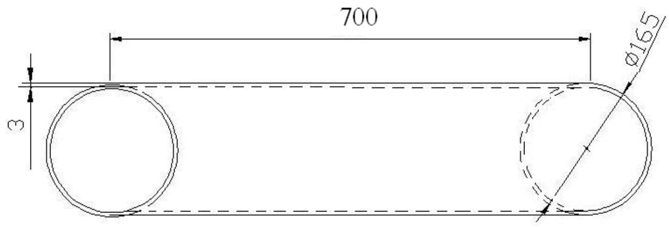


*Figure 7. External cavity dimensions*

Coil L1 consists of two parts, one fixed (A) and the other mobile (B). This is illustrated in Figure 8, the top spot the fixed part and in the bottom of the picture is the mobile part.

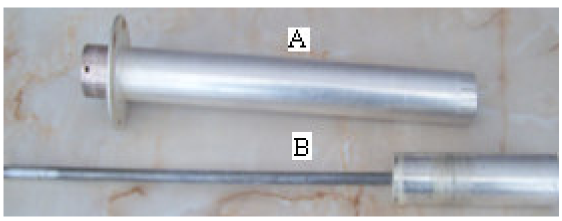


*Figure 8. The fixed and mobile parts of the coil L1*

The fixed part of the coil L1 shown in photo A, has the dimensions shown in figure 9, and the mobile part shown in photo B, has the dimensions shown in figure 10. All dimensions are specified in mm.

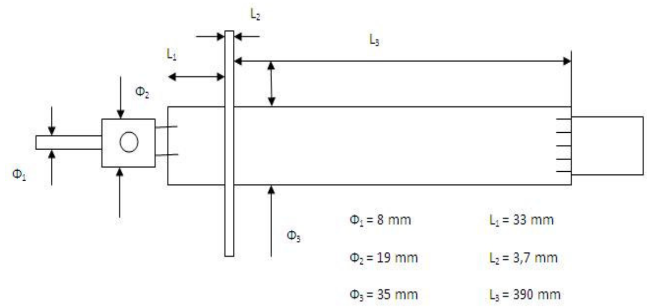


*Figure 9. Dimensions for the fixed part of the coil L1*

The mobile part of the coil L1, corresponding to the image B from the figure 9, is composed of a rod ending with a cylindrical part with diameter Φ3 as it is shown in figure 11.

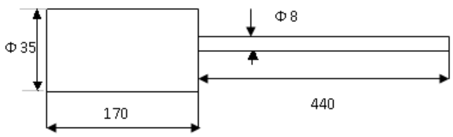


*Figure 10. Dimensions of the mobile part of the coil L1*

The mobile part of the coil L1 is coupled to the fixed part through a threaded screw C, as shown in figure 11. This device allows one to fix the rod axis concentrically with the coil L1. Figure 12 illustrates the final design of the coil L1. By rotating the device C we can change the length of the inner conductor, and the value of the coil L1, consequently.

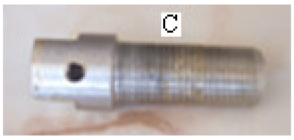


*Figure 11. Threaded screw*

*Figure 12. Upper end of the coil L1*

In figure 13 it is shown the bottom of the coil L1. The image presents the fixed and the mobile parts of the coil and their coupling means.

*Figure 13. Coupling the fixed part of the coil to its mobile one*

The coil is fixed to the outer cavity with six screws.

## IV. ANALYSIS OF THE RESONANT CAVITY

Considering the dimensions of a resonant cavity described in Figures 5 to 11 were calculated values C1 and L1*, these ones representing the linear capacity and the linear inductance of the resonant cavity.

The computed values are summarized in Table 1; their extreme values and the associated resonant frequencies are shown in Table 2.

| inner conductor diameter, [mm] | exterior conductor diameter [mm] | ln(b/a) | linear inductance, | linear capacity |
|---|---|---|---|---|
| 35 | 159 | 1,513556141 | 3,02702E-07 | 3,67554E-11 |

*Table 1. Values of linear inductance and of linear capacity of the resonant cavity*

| inner conductor length [mm] | distance to the end cavity d [mm] | C1 | cavity inductance [H] | cavity capacity [F] | resonance frequency [MHz] |
|---|---|---|---|---|---|
| 390 | 310 | 2,74792E-14 | 1,18054E-07 | 1,14216E-11 | 137,0615484 |
| 560 | 140 | 6,08468E-14 | 1,69513E-07 | 5,2066E-12 | 169,4108356 |

*Table 2. Extreme values of the linear inductance and of the linear capacity of the resonant cavity*

The values in Table 1 are computed considering the permittivity of vacuum $\varepsilon_0$ = 8,854 187 817×$10^{-12}$ F•$m^{-1}$ and permeability of vacuum $\mu_0$ = 4π×$10^{-7}$ N·$A^{-2}$.

The extreme values in Table 2 are obtained for the two extreme values of the inner conductor (minimum length of 390 mm and maximum length 560 mm) using the following formulas:

- capacitor C1 (ability of the free end of the central conductor and coax wall terminal-fig 2), $C1 = \varepsilon_0 \times S/d$; $S = \pi r^2 = \pi D^2/4$;
- capacity cavity C * = C1 + C0 × length inner conductor;
- inductance L1 = L0 × length inner conductor;

We note that the cavity resonance frequency ranges from $f_{min}$ = 137 MHz to $f_{max}$ = 169 MHz depending on the length inner conductor. So, our implementation of a duplexer filter complies with a repeater R7 requirements that specifies the receiving frequency $f_1$ = 145.175 MHz and the transmitting frequency $f_2$ = 145.775 MHz; the values for L and C* could be obtained by adjusting the length of inner conductor using the values in Table 1. This is illustrated in Table 3.

| inner conductor length [mm] l | distance to the end d [mm] | C1 | cavity inductance [H] | cavity capacity [F] | resonance frequency [MHz] |
|---|---|---|---|---|---|
| 472,3 | 227,7 | 3,74113E-14 | 1,42966E-07 | 8,40661E-12 | 145,1753385 |
| 475,92 | 224,08 | 3,80156E-14 | 1,44062E-07 | 8,27416E-12 | 145,7750962 |

*Table 3. Values of inductance and capacity for R7 resonant cavity*

## V. PRACTICAL REALIZATION OF CAVITY RESONANCE

All components of the resonant cavity were made of silver plated copper.

The final form of a cell duplexer filter is shown in the image of Figure 14.

*Figure 14. The image of a cell*

L2C2 circuit does not have an essential role in coaxial cavity resonance; C2 actually makes only an adaptation to the cavity coupling impedance loop current through L2.

Coil L2 is built using a profile with dimensions shown in Figure 15 with the final image shown in Figure 16.

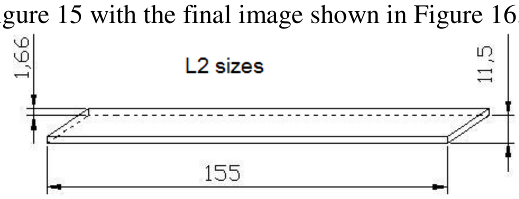


*Figure 15. Dimensions for coil L2*

*Figure 16. Picture of the coil L2*

The capacitor C2 has the dimensions shown in Figure 17.

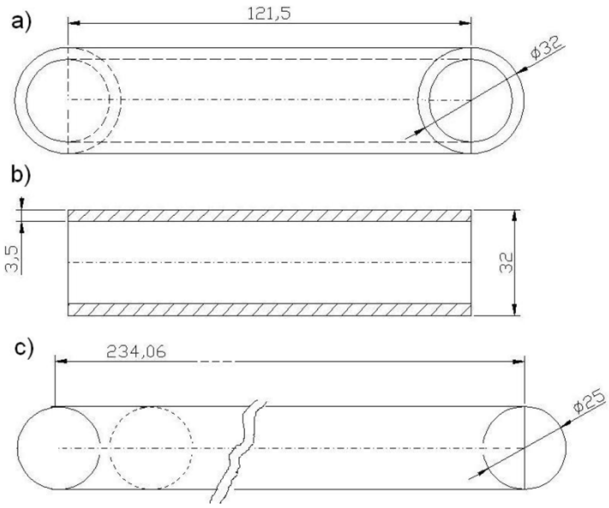


*Figure 17. Dimensions of a) the capacitor C2, b) the cylinder, and c)the polymer dielectric.*

The picture of the capacitor C2 is shown in Figure 18.

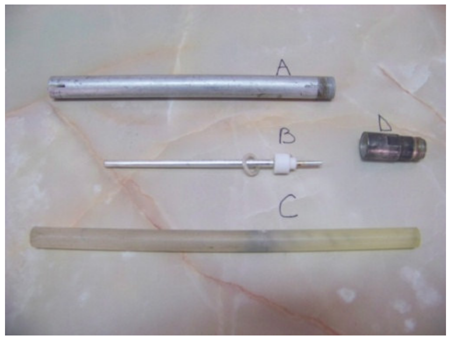


*Figure 18. Photo of the capacitor C2*

## VI. EXPERIMENTAL TESTING

Duplexer filter was realized by coupling two resonant cavities in parallel to a loop antenna for the receiving side and other two resonant cavities to the same loop antenna – for the transmitting side[5],[6]. The operating frequencies $f_{min}$ and $f_{max}$ are spaced at 600 KHz. Parallel connection of the cavities allows for a greater slope of the filter transfer function between the band pass frequency and the band stop one.

Results obtained with the analyzer IFR - Aeroflex 2945 for the filter for reception, frequency 145,175 MHz are illustrated in Figure 19.

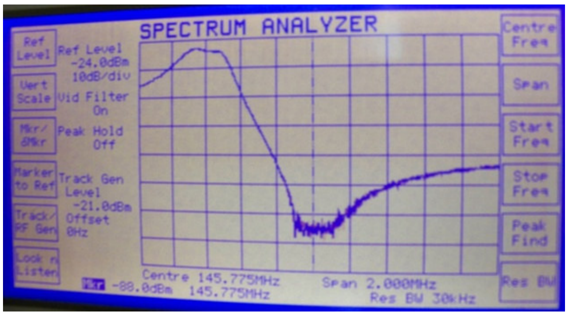


*Figure 19. Feature-cell duplexer filter for receiving mode*

Note that an attenuation of 88 dB at the frequency of 145.775 MHz is obtained, more than the minimum 50 dB required; this results in a better attenuation of the signals coming from the antenna.

The results obtained with the same analyzer for transmission filters, for the other pair of resonant cavities at the same frequency of 145.775 MHz are illustrated in Figure 20.

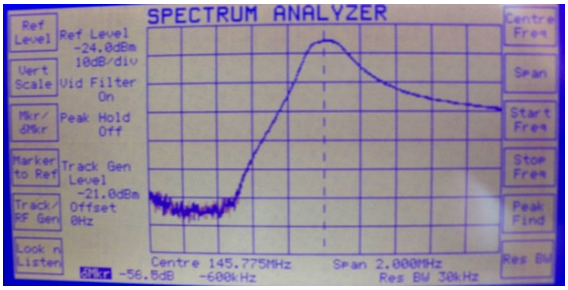


*Figure 20. Feature-cell filter duplexer for transmitting part*

It is noted that mitigation for receiving frequency is 56.5 dB which is again more than the required 50 dB; mitigation is sufficiently good, so the repeater reception is not affected during the transmitting time.

## VI. CONCLUSION

This paper presents the practical implementation and experimental testing of a filter duplexer of a structure repeater in the VHF band. Practical measurements revealed the fulfillment of the required parameters by the implemented duplexer filter.

## REFERENCES

[1] Gh.Sauciuc, I.Bogdan, "*Opportunity of Using Notch Filters in Building Cavity Resonances of Duplexers*", SATEE 2010-Smart Applications & Technologies for Electronic Engineering - International Conference, September 9-11th, 2010, Alba Iulia, ISBN 978-973-1890-27-2, pp. 61-62. http://www.satee.uab.ro/upls/SATEE2010.pdf

[2] http://www.seits.org/duplexer/duplexer.htm

[3] Mourot, L.; Bar, P.; Arnaud, C.; Parat, G.; Carpentier, J.-F., "*Coupled Resonator Filters for W-CDMA Duplexer Application*", IEEE Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems, 2008. SiRF 2008. Digital Object Identifier: 10.1109/SMIC.2008.60 , Publication Year: 2008 , pp. 214-217.

[4] Antena Book 19th Edition, ISBN 0-87259-804-7, August 2000, Chapter 17 pp. 17-14.

[5] Alwi, M.F, "*Four tubing Duplexer using band pass and reject*", Communication Technology, 2008. ICCT 2008. 11th IEEE International Conference on,10-12 Nov. 2008, Digital Object Identifier: 10.1109/ICCT.2008.4716227 , pp. 260-263.

[6] Marie, F. , Oger, M. ; Erhel, Y., "*Design, simulation and test of cavity in UHF band*" , Electronics Letters, September 24, 2009,Volume: 45 , Issue: 20, pp. 1040-1042.