# The Computer Simulation of the High Frequency Interference Influence on the Implantable Pacemakers

A. N. RYZHIKH
Department of Electronics, Moscow Engineering Physics Institute (Technical University), Russia

**Summary**

*The regulation of the allowable levels of the different frequency electromagnetic fields for the implantable pacemakers is a highly actual problem. The preliminary results of many investigators show the dangerousness of the high frequency fields for patients with implanted pacemakers. This means a low effectiveness of the low-pass filters (LPF) used in pacemakers input stages. The goal of this work was to determine the reasons of the poor suppression of the high frequency interference by pacemakers LPF. The simulation of the passive single and multiple stage LPF has been done by PSPICE code taking into account parasitic elements. In this case, an additional pass-band of LPF is appearing in the high frequency range. Thus, one of the main reasons of the low level defense of implantable pacemakers to high frequency electromagnetic fields is given by a parasitic high frequency pass-band of the low-pass filter installed in the input part of pacemakers.*

**Key Words**

Low-pass filter, additional pass-band, pacemaker, high frequency interference

## Introduction

The regulation of the allowable levels of the different electromagnetic field frequencies for the implantable pacemakers is a highly actual problem. The environment impregnation by the electromagnetic radiation is increasing year after year. The quantity of patients with pacemakers extremely increases in the world. The complexity and sensitivity of pacemakers are increasing too in every new generation of pacemakers. This means unfortunately, that the problem of influence of high frequency electromagnetic fields to pacemakers becomes more and more sharp. The preliminary results of many investigators show the dangerousness of the high frequency fields for patients with implanted pacemakers [1-6].

At first, we summarize the main reasons of high frequency electromagnetic fields influence on implantable pacemakers. There are two ways of interference coupling into pacemakers:

- through input electrodes to input electronic stages and further to other electronic parts of pacemakers. Input electrodes work as antennas;
- through intermediate parasitic capacitances to different parts of electronic circuit of pacemakers.

First, way of high frequency interference coupling proposes that low-pass filters (LPF) used in pacemakers input stages are ineffective to prohibit electrical signals with frequencies above cut-off frequency of LPF. Explanation of such behavior of LPF will be given below.

Second, way of high frequency interference coupling provide an influence to pacemaker by following reason. Really, every time we have a superposition of many different electromagnetic fields. Some of them have high frequencies, other have low frequencies, e.g. range of these low frequencies can span "the physiological pass-band" [1]. It means that such low frequency signals can modulate the high frequency signals. When these modulated signals pass through electronic stages of pacemakers detecting or rectifying can take place like in radio-receivers due to parasitic or installed diode structures. Ultimately, detected signals cause malfunctions of pacemaker's performance.

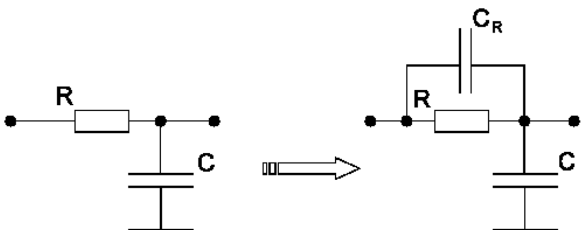


*Figure 1. Simplest low-pass filter (LPF) based on resistor R and capacitor C. At high frequency we need to take into account the parasitic intermediate capacitance $C_R$.*

The goal of this work was to determine the reasons of the poor suppression of the high frequency interference by pacemakers LPF. As pointed out previously [7], an additional pass-band of LPF arises in high frequency range. Thereby, the lowest border of this additional pass-band is in the order of 100 to 1000 times the upper cut-off frequency ($f_H$) defined at 3dB level of the tested LPF.

## Method

The simulation of the passive single and multiple stage LPF has been done by PSPICE code taking into account the parasitic elements. Analysis shows two groups of affected factors:

- intermediate parasitic capacitances leading to straight propagation of high frequency signals from input to output of LPF stages (Figure 1);
- nonideality of capacitors in LPF. It means that equivalent circuit of capacitor in the high frequency range includes not only capacitance but resistance in parallel and inductance in consequence (Figure 2).

## Results

Computer simulation by PSPICE algorithm shows at high frequency range the appearance of an additional pass-band of LPF. The lowest border of the additional pass-band is in the order of 100 to 1000 times the upper cut-off frequency ($f_H$) defined at 3dB level of the tested LPF. In Figure 3 we took into account both parasitic effects, intermediate parasitic capacitance $C_R$ , and nonideality of capacitor C characterized by resistance $R_C$ and inductance $L_C$.

The filter characteristic in the high frequency range may be much more complicated, i.e. several local maxima arise if effective time constants of above mentioned parasitic processes differ much. Of course, filter

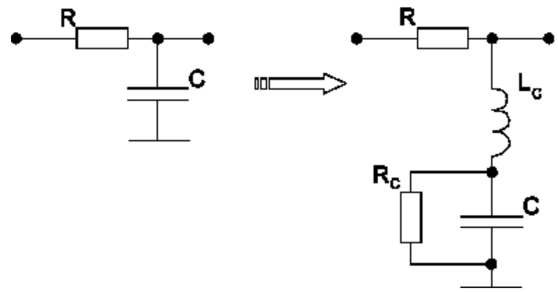


*Figure 2. Simplest low- pass filter (LPF) based on resistor R and capacitor C. At high frequency we need to take into account the parasitic inductance $L_C$ and leakage resistance $R_C$ of the capacitor C.*

characteristic of multistage LPF becomes more effective in the high frequency range [8]. Thus, multistage LPF are used to prohibit high frequency propagation, especially, for cut-off frequencies of the different filter stages lying inside the parasitic pass-bands of other LPF stages. Similar results were found at laboratory checking LPF breadboard constructions.

## Conclusions

One of the main reasons of the low level defense of implantable pacemakers to high frequency electromag-

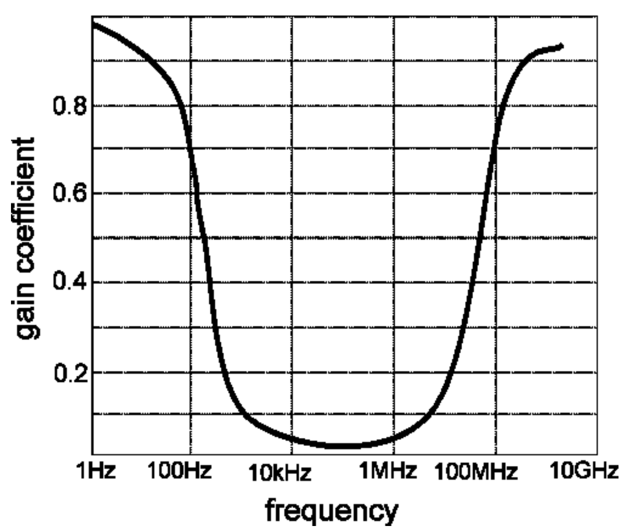


*Figure 3. Frequency characteristic of the real simplest low-pass filter (LPF) calculated by PSPICE code taking into account parasitic intermediate capacitance $C_R$ , parasitic inductance $L_C$ and leakage resistance $R_C$ . Here, $f_H$ = 200 Hz is the upper cut- off frequency. The gain coefifcient increases in the order of 100 kHz to an additional pass band at high frequencies.*

netic fields is given in an additional pass-band of the low-pass filter installed in the input part of pacemakers. High frequency signals pass through such LPF, then, after detecting by the electronic circuit pacemaker work is disturbed.

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