

**RESULTS OF MODELING, DESIGNING AND DEVELOPMENT
OF BAND-PASS ELECTRIC FILTER WITH CROSS-LINKS IN WIDE
RANGE OF ULTRA HIGH FREQUENCY BANDS**

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**РЕЗУЛЬТАТИ МОДЕЛЮВАННЯ, ПРОЕКТУВАННЯ ТА РОЗРОБКИ
СМУГОПРОПУСКНИХ ЕЛЕКТРИЧНИХ ФІЛЬТРІВ З ПЕРЕХРЕСНИМИ
ЗВ'ЯЗКАМИ В ШИРОКОМУ СПЕКТРІ ЧАСТОТ ДЕЦИМЕТРОВОГО ДІАПАЗОНУ**

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Abstract. *The provided analysis shows the need to ensure non-interference operation of radio electronic facilities (REFs) by eliminating the incompatible radio technologies in the adjacent frequency bands or by minimizing interference as far as possible. A presented example based on the cellular communication systems suggests that one of the factors influencing the size of a guard interval is the need to 'filter-out' nearby radio technologies operating in opposite directions of transmission. In such instances, filters shall be used to avoid interference. Filters will allow, in the first place, to create necessary attenuation in the reception band of BS of nearby radio technology to suppress out-of-band and spurious emissions, furnishing by BS own transmitter; and in the second place, to create attenuation in the transmission band of nearby radio technology in order to reduce signals coming from BS transmitters of nearby radio technology at the input of own BS receiver. Additional high slope AFR filters may be required for both the BS transmitters and BS receivers in some frequency ranges in Ukraine. There is one more precondition for usage of high slope AFR filters having the ability to suppress main emission of transmitters by values of 30-40 dB as follows: appropriate radio frequency control and regulatory authorities are required to apply the measuring equipment within dynamic range of 80 dB. The simplified 3D filter models on 9 coaxial resonators with high Q factor which are described in the article are prepared with the help of AWR Microwave office and CST Studio Suite software tools. The simulation of AFR and frequency response for such parameter as filter reflection coefficient is also described in the article. The results of design and research concerning band-pass electric filters that have been obtained on the basis of application of the low-frequency filter prototype method are presented in the article. Prototype models of band-pass electric filters with cross-links in wide range of UHF bands (820–843 MHz and 890–915 MHz, 1920–1980 MHz and 2510–2570 MHz) are designed and produced. As a result of measurements of AFR and frequency response for the filter reflection coefficient, the attenuation within the pass-band frequency range of these filters equals to 1.5–2.0 dB; the attenuation of input signals referring to out-of-band emissions equals to 30–75 dB; the filter reflection coefficient is within minus 13 dB.*

Keywords: *electromagnetic compatibility, cellular communication system, adjacent frequency bands, out-of-band emission, designing, low-frequency filter prototype method, band-pass electric filter, steepness of slope in amplitude-frequency response (AFR), cross-link, ultra-high frequency (UHF) band.*

Анотація: *Наведено аналіз необхідності забезпечення беззавадової роботи радіоелектронних засобів (РЕЗ) шляхом виключення роботи несумісних радіотехнологій у суміжних смугах частот, або зниження їх завадового впливу до мінімального рівня. На прикладі систем стільникового зв'язку показано, що одним з*

факторів, який впливає на розмір захисного інтервалу є необхідність розфільтрування сусідніх радіотехнологій, що працюють в протилежних напрямках передавання. У таких випадках для уникнення завад необхідно використовувати фільтри, які б дали змогу з одного боку створити необхідне затухання в смузі прийому базових станцій (БС) сусідньої радіотехнології для придушення позасмугових та побічних випромінювань власного передавача БС, а з другого - створити затухання в смузі передавання сусідньої радіотехнології з метою зменшення рівнів сигналів від передавачів БС сусідньої радіотехнології на вході приймача власній БС. На території України використання додаткових фільтрів з високою крутизною скатів АЧХ як на передавачах БС, так і на приймачах БС може бути необхідним в деяких діапазонах частот. Наведені результати моделювання, проектування, експериментальних досліджень та випробувань смуго-пропускних електричних фільтрів із перехресними зв'язками в широкому спектрі частот дециметрового діапазону (820–843 МГц та 890–915 МГц, 1920–1980 МГц та 2510-2570 МГц) з використанням методу низькочастотних прототипів фільтрів.

Ключові слова: електромагнітна сумісність, системи стільникового зв'язку, суміжні смуги частот, позасмугові випромінювання, проектування, метод низькочастотних прототипів, смуго-пропускні електричні фільтри, крутизні скатів амплітудно-частотної характеристики, перехресні зв'язки, дециметровий діапазон частот.

INTRODUCTION

Introduction of the latest radio technologies is always associated with the possibility of their use for certain radio frequency ranges. There are a number of documents governing the use of the radio frequency spectrum. The most important of them is the Radio Regulations, according to which the radio frequency spectrum is allocated to different radio services at the global level [1]. At the national level a more detailed allocation of ranges is carried out between specific radio technologies. Such measures aim to ensure non-interference operation of REFs by eliminating incompatible radio technologies in the adjacent frequency bands or by minimizing their interference.

Usually a certain guard interval is established between the reception band of certain radio technology and the transmission band of different radio technology. The guard interval may not be used at all or may be allocated to another radio technology where technical parameters of REF do not cause significant interference to the REFs of different radio technologies operating in adjacent bands. In any case, in order to effectively use the radio frequency resource, it is advisable that values of such guard interval should be as minimal as possible. One of the factors affecting the size of the guard interval is the fact that nearby radio technologies, operating in opposite directions of transmission, are not 'filtered-out'. This is demonstrated in an example based on the use of cellular communication systems with transmission band of the base station (BS) of certain radio technology located near the BS of different radio technology. Usually, BSs are located on the roofs of buildings or on masts and towers and are equipped with high gain antennas (up to 15-18 dB), meaning that in most cases there is a direct line of sight between the antennas of BSs of different radio technologies with the total antenna gain on the radio line up to $G_{a1+a2} = 36$ dB. It should be noted that REF transmitters have certain levels of out-of-band and spurious emissions, which can fall into the reception band of REFs of nearby radio technology, and in view of the high G_{a1+a2} values and small distances between BSs, can create unacceptable interference. In addition, high signal levels at the inputs of BS receivers from BS transmitters of nearby radio technology can cause intermodulation interference or receiver blocking. In such cases it is required to use filters with a view to prevent interference. Filters will, on the one hand, create necessary attenuation in the receiving band of BS of nearby radio technology in order to suppress out-of-band and spurious emissions of the own BS transmitter, and on the other hand, create attenuations in the transmission band of nearby radio technology in order to reduce signals from transmitters of BS of nearby radio technology at the input of the own BS receiver.

AIMS OF EXPERIMENTAL RESEARCH

Experience suggests that in most cases the desired values of filter attenuation in the frequency bands of nearby radio technologies should be 45 dB or more. Such attenuation can be formed directly in the receiving and transmitting filters of duplexers; or if duplexer filters do not

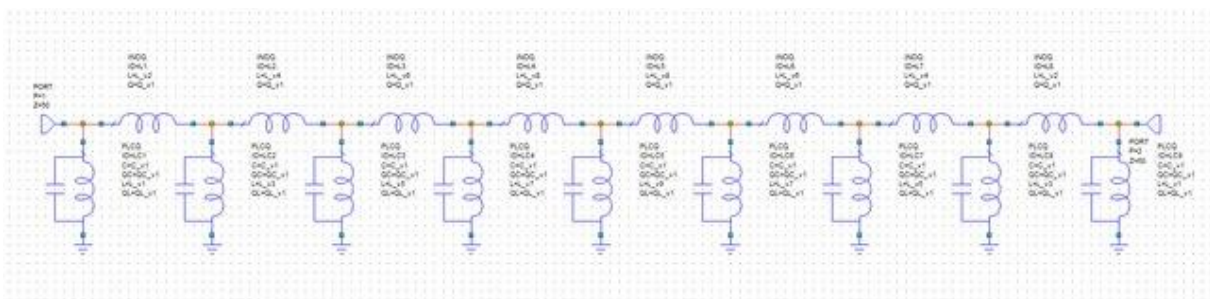
ensure the necessary attenuation, additional filters shall be used in the corresponding paths. By so doing, it is well to bear in mind that the specified attenuation in the band of nearby radio technology shall be created under the condition of minimal attenuation in the own band. That is, the value of the guard interval between different radio technologies shall be no less than the frequency band in which specified AFR filters can be implemented. Therefore, the use of high slope filter has an effect on the efficiency of the use of the radio frequency resource. This is especially important for Ukraine, where radio technologies are traditionally used in the frequency ranges that are not yet harmonized with European ones, and telecom operators own licenses without the use of guard intervals. Under such conditions the use of additional high-slope AFR filters for both BS transmitter and BS receiver becomes mandatory.

The following case demonstrates another possible application of the filters: the authorities conducting monitor of the use of the radio frequency resource, are assigned with a task to monitor the levels of out-of-band emissions furnished by REFs. This task is not simple, since the levels shall be measured with closely spaced main transmitter emission of more than 100 dB spectral power density. Taking into account that the equipment used for measurement of out-of-band emission has a dynamic range of not more than 80 dB, there is a need for the use of high-slope AFR filters suppressing the main transmitter emission by 30-40 dB, which is equivalent to reducing the dynamic range of measured signals by the same value.

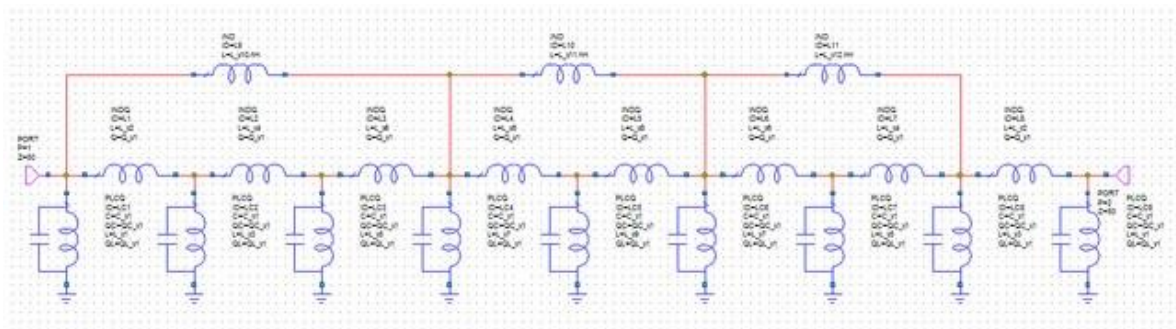
This paper presents the results of modeling, designing, experimental research and testing of bandpass electric filters in a wide range of UHF bands using the low-frequency filter prototype method according to [2 and 3].

MODELING AND DESIGNING OF BAND-PASS ELECTRIC FILTERS

To meet requirements of the Terms of Reference for 890–915 MHz band-pass filter, namely, to achieve at least 30 dB suppression (attenuation) of the input signal at 887.5 MHz frequency (2.5 MHz difference between the attenuation band and the pass band), it was decided to make calculation using the *filter with cross-link theory* [4, 5, and 6]. Figure 1 shows electric circuits of low-frequency band-pass filter prototypes.



a)



b)

Figure 1 — Electric Circuits of Low-Frequency Prototypes:
 a) 1920-1980 MHz and 2510-2570 MHz filters
 b) 820-843 MHz and 890-915 MHz filters with cross-links

Next step was to set the simplified 3D filter models using nine high-quality coaxial resonators (Fig. 2) and to simulate amplitude-frequency characteristics and frequency characteristics of the reflection coefficient using up-to-date AWR Microwave office and CST Studio Suite software.

Figure 3 shows the graphs of 2510-2570 MHz filter simulated characteristics.

During a stage of three-dimensional filter modeling and designing, a lot of work was done to increase the number of identical filter components. As a result of these works, it became possible to use the same resonant cavities (volumes) and links between them (i.e., use of one housing to configure filters for all four bands), and referring to the 820 MHz and 890 MHz filters, the similar resonator shape was fitted.

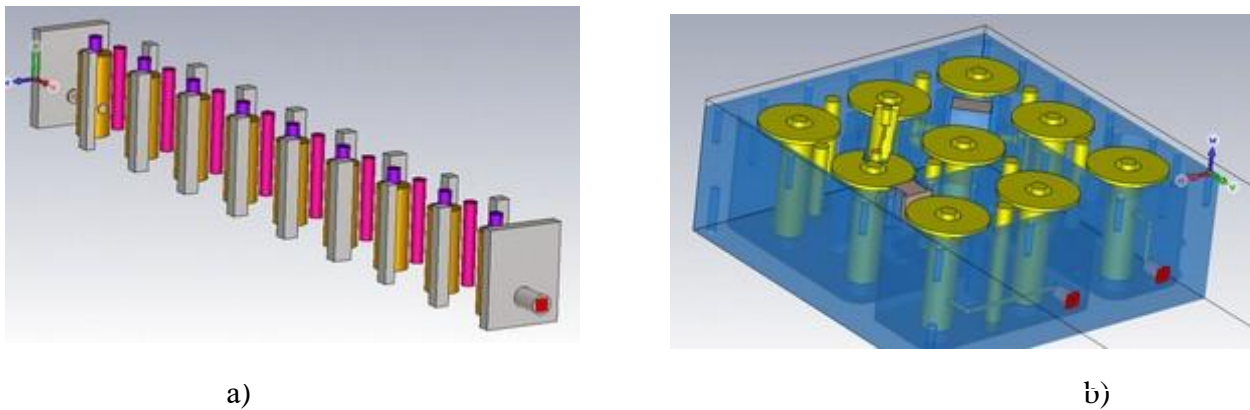


Figure 2 — simplified 3D filter models:
 a) 1920 MHz and 2510 MHz;
 b) 820 MHz and 890 MHz

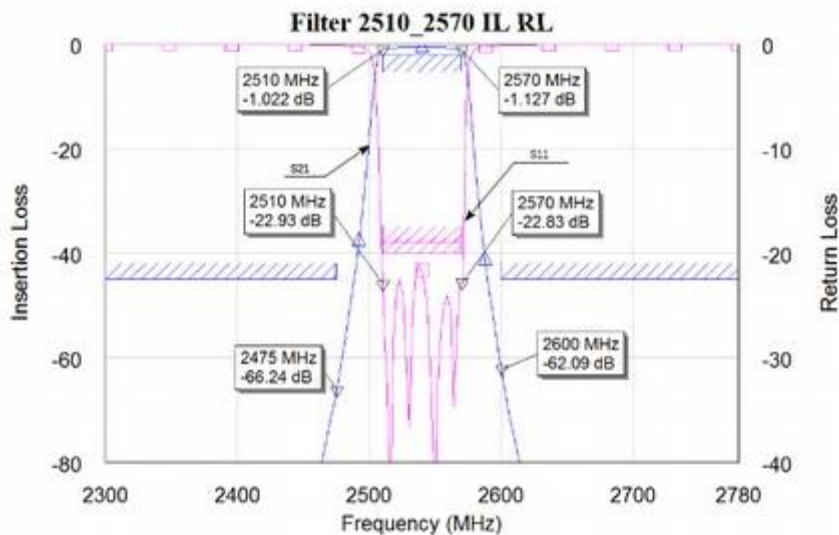


Figure 3 — Simulated amplitude-frequency characteristic and frequency characteristic of the reflection coefficient of 2510-2570 MHz filter

Results of Experimental Studies and Testing

To conduct experimental studies and testing of simulated objects, the filter samples with nine coaxial resonators were manufactured.

“ФC-2510-2-40” band-pass filter was set to 2540 MHz central frequency with filter pass-band of 60 MHz. According to the measured values of amplitude-frequency characteristics and frequency characteristics of the reflection coefficient (Fig. 4, a)), attenuation in the filter pass-band was 1.2 ... 1.5 dB; attenuation of the input signals at 1000 MHz to 2475 MHz frequencies was more than 50 dB; and at 2600 MHz to 3000 MHz frequencies was more than 45 dB. The reflection coefficient was -13 dB, which fully met the Terms of Reference for this filter.

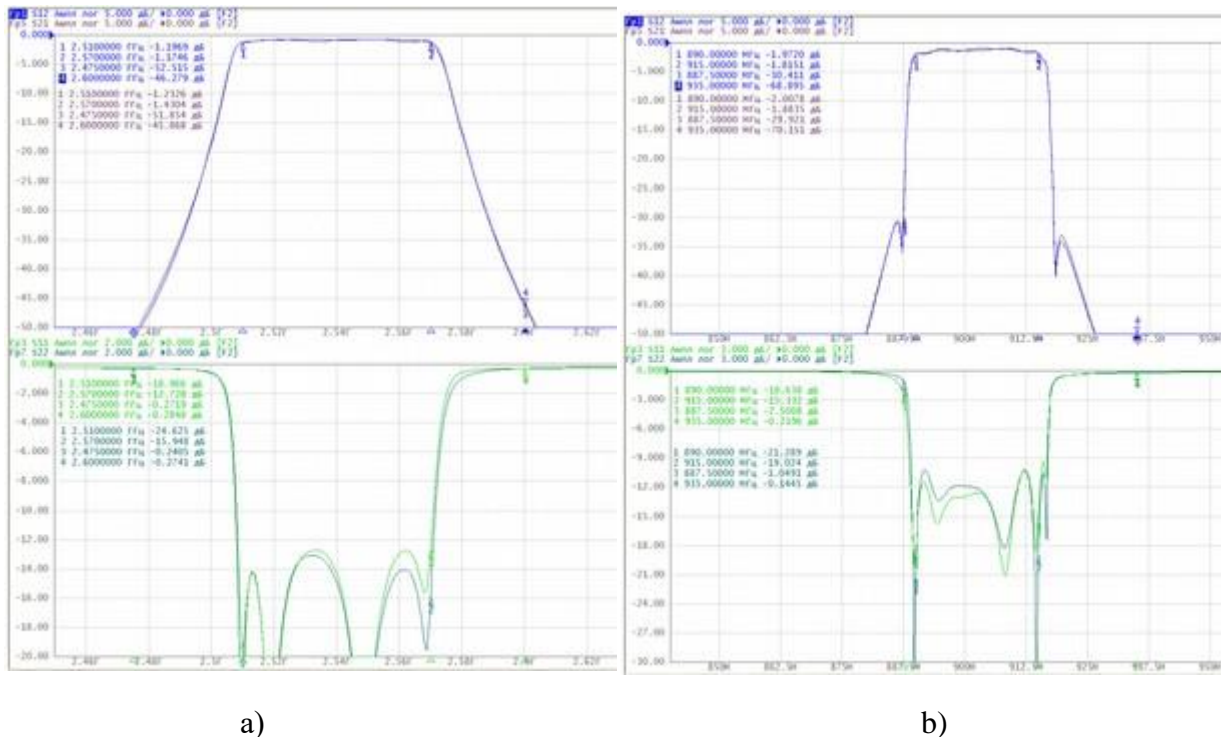


Figure 4 - Measured amplitude-frequency characteristics and frequency characteristics of the reflection coefficient: a) “ФC-2510-2-40” band-pass filter; b) “ФC-890-2-30” band-pass filter

“ФC-890-2-30” band-pass filter was set to 902,5 MHz central frequency with pass band of 25 MHz. When setting 2.5 MHz back from the edge of pass band at 887.5 MHz frequency, the attenuation of input signal was more than 30 dB (Fig. 4, b)), which protects measuring equipment from the effects of high level radio frequency emission created by cellular base stations. Characteristics of the designed band-pass filters are shown in Tables 1-4:

Table 1 - Technical characteristics of “ФC-820-2-30” band-pass filter

No.	Parameter	Measured value
1.	Pass band, MHz	820-843
2.	Loss in pass band not more, dB	1.42
3.	Attenuation not less, dB	
	100-800 MHz	65
	870-2000 MHz	75
4.	SWR in pass band, not more	1.8

Table 2 - Technical characteristics of “ФC-890-2-30” band-pass filter

No.	Parameter	Measured value
1.	Pass band, MHz	890-915
2.	Loss in pass band not more, dB	2.05
3.	Attenuation not less, dB:	
	100-887,5 MHz	30
	935-960 MHz	65
4.	SWR in pass band, not more	1.9

Table 3 - Technical characteristics of “ФC-1920-2-30” band-pass filter

No.	Parameter	Measured value
1.	Pass band, MHz	1920-1980
2.	Loss in pass band not more, dB	1.68
3.	Attenuation not less, dB:	
	1000-1900 MHz	40
	1920-1980 MHz	40
4.	SWR in pass band, not more	1.55

Table 4 - Technical characteristics of “ФC-2510-2-40” band-pass filter

No.	Parameter	Measured value
1.	Pass band, MHz	2510-2570
2.	Loss in pass band not more, dB	1.48
3.	Attenuation not less, dB:	
	1000-2475 MHz	51
	2600-3000 MHz	45
4.	SWR in pass band, not more	1.65

CONCLUSION

The demonstrated example based on the use of cellular communication systems shows that one of the important factors in the issue of electromagnetic compatibility in mobile communication networks, which influences the size of guard interval, is the need to ‘filter-out’ nearby radio technologies operating in opposite directions of transmission.

A lot of band-pass electric filters with cross-links in wide range of UHF bands (820-843 MHz and 890-915 MHz, 1920-1980 MHz and 2510-2570 MHz) were developed using the low-frequency filter prototype method that ensures the control of receiving bands of base stations of cellular (mobile) communications and the protection of measuring equipment from output emission of base stations.

Feasibility of designed high-slope AFR filters and their subsequent implementation in the cellular networks are factors which will significantly improve the efficiency of the use of the radio frequency resource.

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