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DESIGN AND MODELING OF BAND-PASS FILTERS ON COAXIAL RESONATORS FOR THE CELLULAR COMMUNICATION SYSTEMS

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The provided analysis shows the need to ensure non-interference operation of radio electronic facilities (REF) 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 the base station (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 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. This article contains the results of modeling, designing, experimental research and testing of the band-pass electric filter with cross-links in a wide range of UHF bands (820-843 MHz and 890-915 MHz, 1920-1980 MHz and 2510-2570 MHz) using the low-frequency filter prototype method.

KEY WORDS: *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*

1. INTRODUCTION

The introduction of the latest radio technologies is always associated with the possibility of their use for certain radio frequency ranges. A few documents are 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, more detailed allocation of ranges is carried out between specific radio technologies. Such measures aim to ensure non-interference operation of REF 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 REF of different radio technologies operating in adjacent bands. In any case, in order to effectively use the radio frequency resource, it is advisable that the values of such a 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 the transmission band of the base station (BS) of certain radio technology located near the BS of different radio technology. Usually, BS are located on the roofs of buildings or 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 BS 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 REF of nearby radio technology, and in view of the high G_{a1+a2} values and small distances between BS, can create unacceptable interference. Also, 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 preventing 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.

2. 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 a high slope filter influences 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 REF. 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.

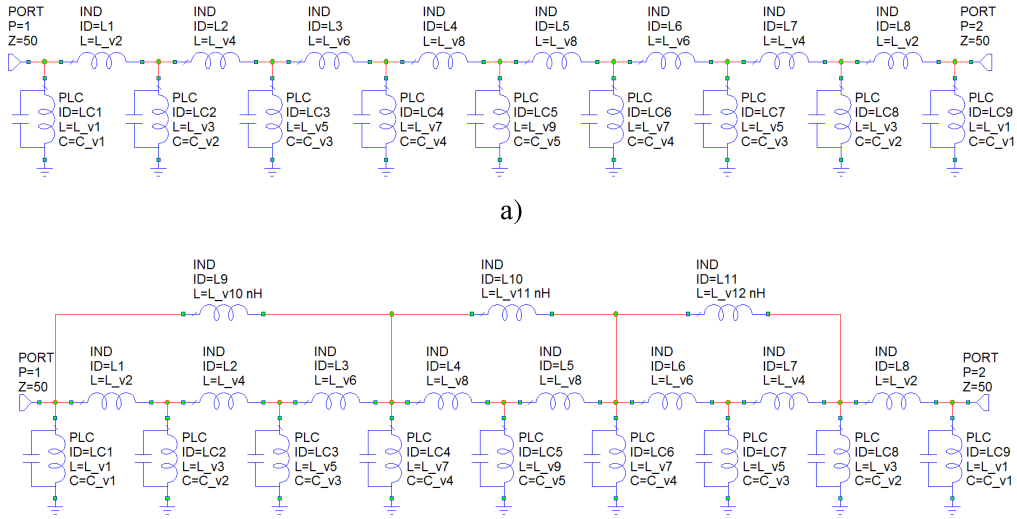
This paper presents the results of modeling, designing, experimental research, and testing of bandpass electric filters in a wide range of UHF bands using the low-frequency filter prototype method according to [1,2].

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 passband), it was decided to make a calculation using the filter with cross-link theory [3-5]. Figure 1 shows the electric circuits of low-frequency band-pass filter prototypes.

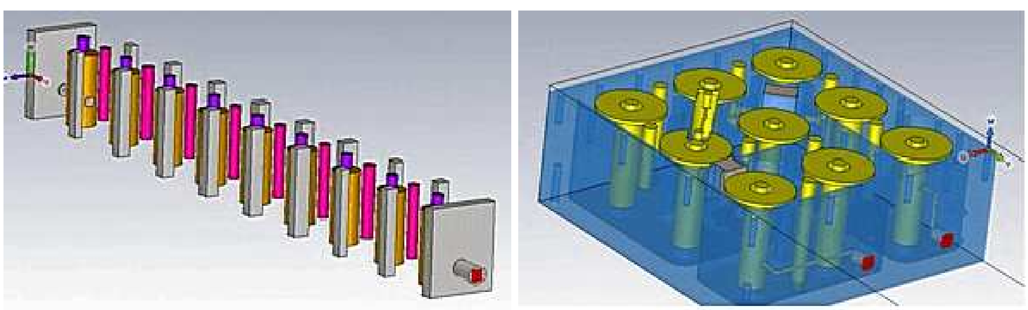
The next step was to set the simplified 3D filter models using nine high-quality coaxial resonators (Fig. 2) and to simulate amplitude-frequency characteristics and frequency characteristics of the reflection coefficient using up-to-date AWR Microwave office and CST Studio Suite software. Figure 3 shows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



b)

FIG. 1: Electric circuits of low-frequency prototypes: a) 1920-1980 MHz and 2510-2570 MHz filters; b) 820-843 MHz and 890-915 MHz cross-links filters



a) b)

FIG. 2: Simplified 3D filter models: a) 1920-1980 MHz and 2510-2570 MHz; b) 820-843 MHz and 890-915 MHz

4. RESULTS OF EXPERIMENTAL STUDIES AND TESTING

To conduct experimental studies and testing of simulated objects, the filter samples with nine coaxial resonators were manufactured. “BF-2510-2-40” band-pass filter was set to 2540 MHz central frequency with a filter passband of 60 MHz. According to the measured values of amplitude-frequency characteristics and frequency characteristics of the reflection coefficient (Fig. 4), 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.

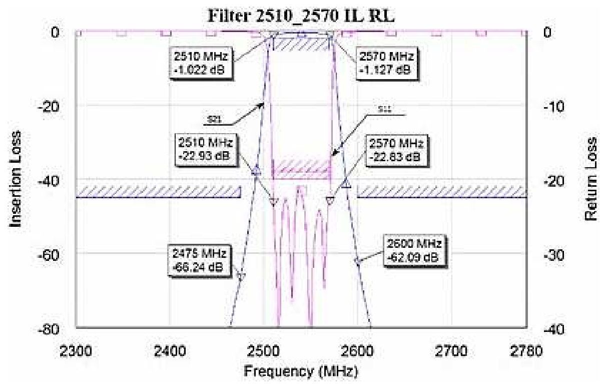


FIG. 3: Simulated amplitude-frequency characteristic and frequency characteristic of the reflection coefficient of the 2510-2570 MHz filter

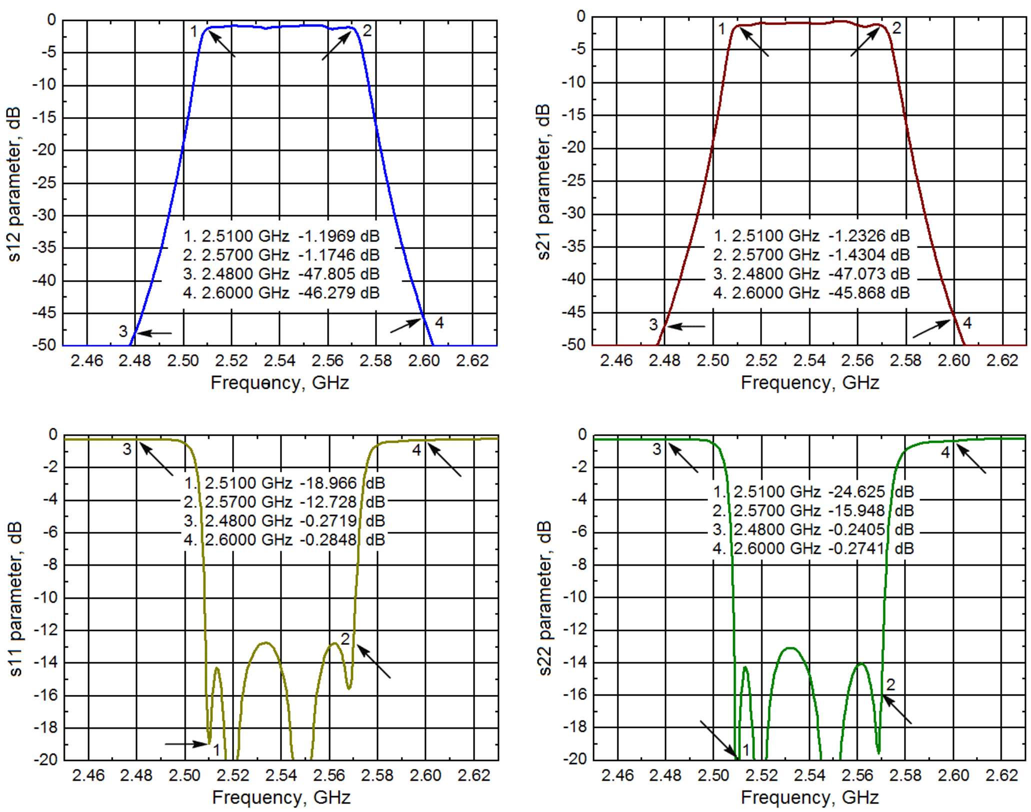


FIG. 4: Measured amplitude-frequency characteristics and frequency characteristics of the reflection coefficient for “BF -2510-2-40” band-pass filter

“BF -890-2-30” band-pass filter was set to 902.5 MHz central frequency with a pass band of 25 MHz. When setting 2.5 MHz back from the edge of passband at 887.5 MHz frequency, the attenuation of the input signal was more than 30 dB (Fig. 5), 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 Table 1.

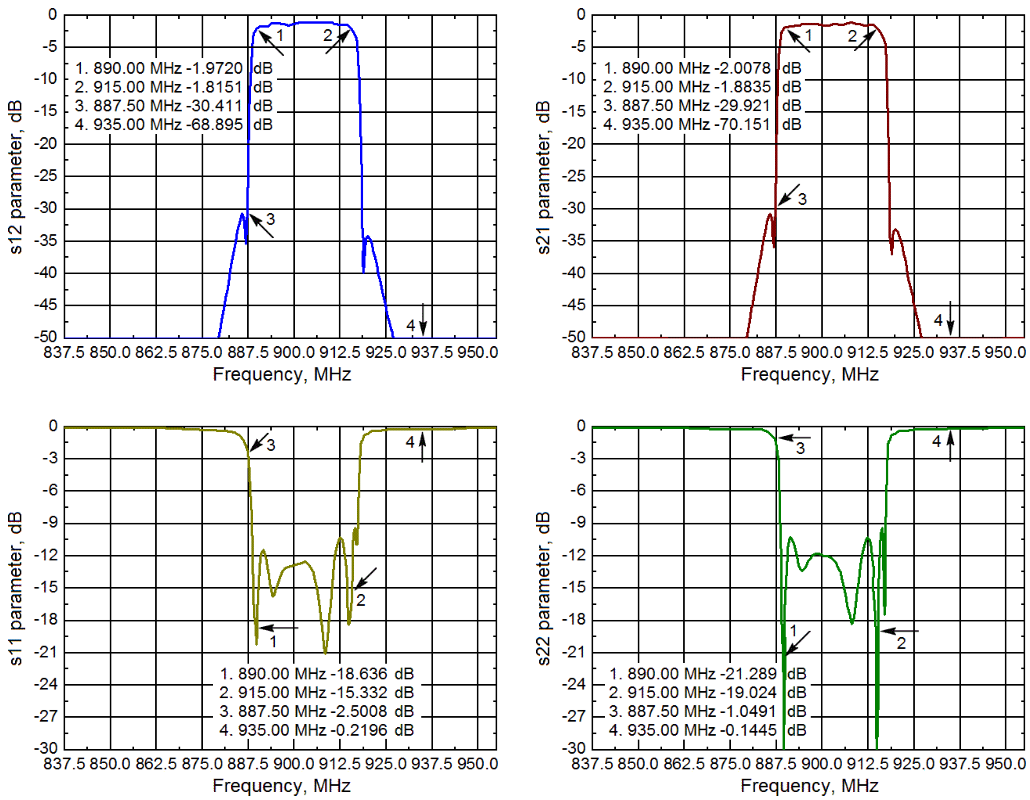


FIG. 5: Measured amplitude-frequency characteristics and frequency characteristics of the reflection coefficient for “BF -890-2-30” band-pass filter

TABLE 1: Technical characteristics of designed band-pass filters

Parameter	BF -820-2-30	BF -890-2-30	BF -1920-2-30	BF-2510-2-40
Pass band, MHz	820-843	890-915	1920-1980	2510-2570
Loss in band-pass, dB	< 1.42	2.05	1.68	1.48
Attenuation, dB	> 65 (100-800 MHZ) > 75 (870-2000 MHz)	30 (100-887.5 MHz) 65 (935-960 MHz)	40 (1.0-1.9 GHz) 40 (1.92-1.98 GHz)	51 (1.0-2.475 GHz) 45 (2.6-3.0 GHz)
SWR in band-pass	< 1.8	1.9	1.55	1.65

5. CONCLUSIONS

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 a 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 that will significantly improve the efficiency of the use of the radio frequency resource.

REFERENCES

1. Slobodyanyuk, P.V., Narytnik, T.M., Blagodarny, V.G., Saiko, V.G., et al., (2012) Theory and practice of radio frequency resource management, *Manual. State University Information and Communication Technologies Publ*., Kyiv, Ukraine: 596 p., (in Ukrainian).
2. Matthaei, George L., Young, Leo, and Jones, Edward M., (1963) *Microwave Filters, Impedance-Matching Networks, and Coupling Structures. Vol. 2*, McGraw-Hill Book Company, New York, San Francisco, Toronto, London, 1080 p.
3. Ness, J.B., (1998) A unified approach to the design, measurement, and tuning of coupled-resonator filters, *IEEE Transactions on Microwave Theory and Techniques*, **46**(4), pp. 343-351. DOI:10.1109/22.664135
4. Korsak, V.F., Narytnik, T.M., Voitenko, O.G., Porshnev, V.L., and Lutchak, O.V., (2014) Frequency sampling device for radio monitoring of cellular base stations of the CDMA-800 standard, *Trans. of the 4th International Scientific and Practical Conference "Infocommunications - Present and Future"*, *1*, pp. 51-54, (in Ukrainian).
5. Korsun, V.I., Korsak, V.F., Narytnik, T.M., and Lutchak, O.V., (2017) The latest solutions to ensure electromagnetic compatibility of base stations of communication systems in adjacent frequency bands, *Trans. of the 6th International Radioelectronic Forum "Applied Radioelectronics. Status and prospects of development"*, **1**, pp. 273-277, (in Ukrainian).