NSF Grant GK-31634

Report

on the

INTERNATIONAL FILTER SYMPOSIUM

Miramar Hotel, Santa Monica, California

April 15-18, 1972

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Technical Report Number R-72-06

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October 15, 1972

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I. The Symposium

On Saturday afternoon through Tuesday moring, April 15-18, 1972, the International Filter Symposium was held at the Miramar Hotel in Santa Monica, California. For some years prior there had been recognized a need for such a symposium at which specialists in the area of electric wave filters could congregate and discuss ideas as a group; the overwhelming success of the Symposium shows that it did meet a significant need.

Undoubtedly the need has been recognized by many individuals, for example Dr. W. Spencer organized a successful session in the area at the 1969 Asilomar Conference and yearly short courses appear at various institutions around the country. But the organization of a major symposium only became a reality when P. Geffe found receptive enthusiasm in the Electrical Engineering Department of the University of Maryland. From the acceptance in October 1970 by Professor N. DeClaris of a proposal for the Symposium by P. Geffe and R. Newcomb quickly developed a structure whose organizational roster is given in Table 1. Besides the enthusiastic support given by a majority of people on that roster, the suggestions toward Symposium Objectives and the award of travel and Symposium support by NSF, through Grant GK-31634, have insured the success and international flavor of the Symposium. Here we record various outcomes of the Symposium with primary emphasis upon the NSF Session, Section II, and questionnaire, Section III.

Table 1

ORGANIZATIONAL ROSTER

1. Host:

Nicholas DeClaris
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4. Technical Program Committee:

S. Darlington, P. R. Geffe, J. F. Kaiser, G. S. Moschytz, R. W. Newcomb, J. D. Schoeffler, W. J. Spencer, G. Szentirmai, L. Weinberg, A. Zverev; Mrs. A. Skees (Secretary)

5. Sponsorship Committee:

V. Belevitch (Belgium); J. Bingham (USA); J. Colin (France); S. Darlington (USA); C. Desoer (USA); A. Fettweis (West Germany); T. Fujisawa (Japan); J. Kaiser (USA); J. Orchard (USA); R. Saal (West Germany); J. Skwirzinski (England); G. Szentirmai (USA); G. Temes (USA); E. Ulbrich (West Germany); H. Watanabe (Japan); L. Weinberg (USA); A. Zverev (USA)

6. Local Arrangements Chairman:

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7. Local Arrangements Committee:

R. Bauer, T. Cotter, N. Levan, H. J. Orchard, G. Temes

8. Toastmaster:

J. A. C. Bingham

9. European Coordinator:

A. Fettweis

10. NSF Conference Research Assistant:

Miss C. Kulkarni

11. Secretarial Assistance:

Mrs. B. Scheu (University of Maryland)

12. Institutional Sponsors:

Electrical Engineering Department, University of Maryland

Department of System Science,
Department of Electrical Science and Engineering
School of Engineering and Applied Science; and
Continuing Education in Engineering and Science,
University Extension, University of California,
Los Angeles

Partially supported by National Science Foundation

A copy of the Symposium Program is given in Appendix b) where it can be seen that the initial talk was given by Dr. S. Darlington. Dr. Darlington set an excellent tone for the Symposium by emphasizing the relationship among the papers to be presented, some of the historical background for most topics of present interest, and the historical interplay of theory with practice. His tables of filter development and topics with relation to the papers presented are given in Appendix g) from which the planning of the Program Committee in trying to obtain cross-fertilization of topics also shows up.

This paper was followed by sessions where the attendees rarely drifted away. Although there was a slight preponderance of university presented papers the industrial attendees did outweigh those from universities yielding an interesting interplay of ideas. Toward this interplay the Monday evening session "International Survey of Filters" presented surveys of developments around the world, primarily with an eye toward practical uses within the last 15 years. Outlines of two of these (for Japan and the USSR) are given in Appendix f) while Dr. W. Poschenrieder gave a well integrated treatment of the developments, especially in the active circuits area, in Western Europe. Dr. J. Young gave a look to the future illustrating the considerable increase in filter useage coming up.

These various sessions led up to the culminating one to which we now turn.

II. Results of the NSF Session: Current and Future Filter Status

The session on Current and Future Filter Status was chaired by Professor R. Newcomb with a view toward fulfilling some of the announced objectives of the Symposium (Appendix d)):

1. Delineation of the major recent results in and status of the filter field.
2. Indentification of important unsolved problems and establishment of priorities for them.
3. Indentification of organizations and their capabilities in the filter field on a world wide basis.
4. Delineation of background needed to work with the main new ideas and results in the filter field.

The participants on the panel were: Professor O. V. Alekseyev (Leningrad), Dr. S. Darlington (Bell Laboratories), Mrs. F. T. El-Mokadem (Cairo, student), Professor A. Fettweis (Bochum), Miss C. Kulkarni (Maryland, student), Dr. W. Poschenrieder (Siemens), Mr. A. Riederer (New York, student), Professor R. Saal (Munich), Mr. J. K. Skwirzynski (Marconi), Dr. H. Watanabe (Nippon Electric), Professor L. Weinberg (CCNY), Professor (Mrs.) K. Zaki (Maryland), Dr. A. Zverev (Westinghouse). This group represents as diverse a cross-section as possible within 13 people (as to world-wide locations, male-female catagories, and student, professorial and industrial expertise); all except Dr. Poschenrieder had their travel partially funded by NSF. Audience participation was encouraged, there being present approximately 30 others than the listed panel (at this time the Circuit Theory Symposium had scheduled a (popular) session, contrary to prior agreements). Almost all of the discussion centered on Item 2, mentioned above, with some comments on Item 4; the other items are covered by the questionnaire, appendix c), with these results summarized in Section III.

Here we summarize the various viewpoints in order of presentation, as follows. These are paraphrased and interpreted, sometimes broadly by R. Newcomb.

1. S. Darlington: One of the most important problems is that of determination of a standard package for integrated analog filters. With the advent of LSI and its increasing complexity for a fixed small size this becomes more critical. And though the actual manufacturing is competitive, industry and university can cooperate on

2. A. Zverev: The invention of surface wave devices was a a great happening which solves many practical problems. Now theoretical and physical treatments in depth are needed. Determination of basic structures in terms of micrographic phenomena with a new outlook would prove valuable.

The concept of transversal filtering in terms of surface wave structures as well as that of charge coupled devices and bucket brigades for intricate filtering could stand investigation.

3. L. Weinberg: It may be that some form of standard modules and off-the-shelf items could be useful for analog and digital filters and circuits as they are for digital logic circuitry. This could lead to desirable LSI implementation. Industry should be convinced of the need for study of this area. To make such a program effective a close coupling of university research to industrial design and development and, in addition, industrial support of university research would be desirable. At the very least one of the results most probably would be the ability to obtain LSI digital filters and possibly active analog circuits.

4. S. Darlington: Until now the cost of not customizing LC filters has not been great but with the advent of LSI the situation is reversing. One has though the problem of communication between theoreticians and solid state designers.

5. L. Weinberg: We also have the problem of computer-aided design where today educators are apparently taking a wrong viewpoint by emphasizing design by "sitting at the console" rather than by a knowledge of filter theory.

5. (con't) I am acquainted with the filter design philosophy of Nippon Electric in Japan. Their philosophy is good in that a coupling of filter theory knowledge is required of computer-aided designers. The overuse of optimization can be a waste of time especially without a basic knowledge of filter techniques and when used in a brute force way. Thus, it might be worthwhile to require a knowledge of basic filter theory and of its power and potential as part of the background of most electrical engineers.

6. S. Darlington: If all of future filter theory is a set of programs we will have no progress and a widening gap between technicians and the professionals will develop.

7. J. Skwirzynski: Manufacturers have not made an impact on those who make specifications. For example, most FM systems are overspecified. Presently no useful theory of specifications seems to exist and people look to available texts which have purely analytic coverage with no relation to economy and practical construction. There exists a big gap also between the communications system designer and the circuit designer; this is an area where universities could help out.

8. H. Watanabe: For some time the programs at Nippon Electric have been such that high school girls can run them but day by day the Ph.D.'s improve them. More numerical analysis seems needed in the engineers' background while also useful are sparse matrix techniques, modern analysis methods using graph theory and topological degrees of freedom, sensitivity and optimization. A good theory for the practical analysis of very large networks is needed.

9. L. Weinberg: A significant problem is the effect of physical layout on the operation and cost of a large filter. We need to know more about the cost benefits that can be obtained before we can make intelligent use of graph theory for the design of integrated circuit filters.

10. H. Watanabe: At this point it appears that differences in layout don't critically affect filtering.

11. L. Weinberg & H. Watanabe: Presently scattering matrices are being used considerably in lumped-parameter filter design but it seems there could be a larger interchange of ideas with the microwave field. Many designs of microwave filters could benefit from the application of modern filter theory. n-port theory as such does not seem to have yet found extensive uses.

12. O. Alekseyev: A fruitful and practical area for research does seem to be that of multiport filtering as for multiplexing. Or for solid-state RF sources which feed several loads more theoretical work is needed now for optimal designs.

13. A. Fettweis: Multiport theory is esthetically pleasing and serves as good background but such structures are often delicate to build. An exception appears to be in the area of AD filtering, as for example wave digital filters including directional filters. One could generalize to other structures, for example that of a multiport digital filter theory.

14. S. Darlington: There may be profit in considering multiports broken into sections; the type 21 repeater uses my 4-port filter though its actual use has been somewhat restricted.

15. A. Fettweis: As yet it seems that there is no major manufacturing problem which critically depends upon multiport theory.

16. L. Weinberg: I can think of problems of multiplexing and high-pass-low-pass filters where at least 3-port theory might be useful. One such case that might be looked at with profit is high-fidelity systems where filters are used to separate the high and low frequencies and send them to different speakers. Clearly, n-port theory is elegant in its results and more thought should be given to making it useful in practice.

17. W. Poschenrieder: If a practical theory is made it will be used; at least it will at Siemens. Siemens makes a number of different types of filters with microwave filters designed in the same department as the others.

Universities don't seem to understand industrial needs. For example most often the most economical solution is desired and this need not lead to an integrated structure.

18. L. Weinberg: Siemens is then different from most large companies in the United States. I wish they were more like Siemens and Nippon Electric, with regard to the practical value of filter theory resulting from university research, the point should be made that the university mission is not to be concerned with economic criteria in its research, especially when the university is ill equipped to formulate such criteria. Surely a closer coupling with industry and financial support from industry would help to alleviate the situation.

19. A. Fettweis: Presently standardization is fixed by the market structure and much of the filter market is not an open one.

20. A. Zverev: Actually n-ports are used every day and their structures are popular. For example the doppler information extractor with 47 outputs in some radar systems. Perhaps then more applications of theory in this field could be profitably sought.

21. R. Saal: Engineers out of the university need a basis upon which to learn new ideas and meetings of this kind are a stimulation in that direction. Topics of interest would be layout techniques for other than LSI structures. It would be useful to have a theory developed for thick film devices especially as applied to RC active structures.

22. F. Glynn: We need improved means of getting information from the universities into the research and development centers of semiconductor manufacturers. Presently the exact size of the electronic filter industry does not seem to be known though in some sectors it is reported as a small economy. However, it may well approach $10 million annually.

23. W. Poschenrieder: One of the greatest filter needs is a thorough and practical RLC synthesis. With better components we need better theories while if we use predistortion we get bad sensitivities.

24. A. Fettweis: Methods based on Bode's idea of introducing additional resistances might be more useful in this regard but as yet there is not an adequate theory for optimization for low sensitivities.

25. J. Skwirzynski: Insertion loss and reflection loss can be considered as independent quantities which could be taken into account in optimization. This is a habitual method used by us with a fair success, particularly when designing multiport filters where interaction plays a major part.

26. S. Darlington: A classical technique is to build and then put in an equalizer.

27. W. Poschenrieder: But this illustrates a non-economical solution.

28. H. Watanabe: RLC synthesis has proven most useful. Also practical constructions have resulted from n-port functional equations (as yet unpublished) from which algorithms have been generated giving a strong tool of optimization.

29. W. Spencer: It appears that continued new developments will be made in new devices and components, as surface waves and new types of integrated circuit chips. Thus a meeting of this kind would profit from including device people in the future. Circuit theory proceeds rather slowly, making a couple of db improvement in signal to noise ratio. One thus would desire mathematical concepts to be developed for new devices as they appear, say today for coupled resonators.

30. E. Christian: Although the theory of devices may be important the need for good circuit theory is even more so in the design of practical filters. Synthesis has its two aspects: 1) approximation, etc., and 2) realization. The latter can be very creative as there are usually 10^6 ways of doing things. Students should therefore be encouraged to design configurations to form the basis for a practical experience with a view toward manufacturing.

31. J. Burnsweig: We are faced with the problem of different technologies running forward. Certainly network theorists are needed to work on the new technologies, such as solid state power generation where people without the networks' background can't make the network theories practical.

31. (con't) Presently there is the problem of making matching networks for TRAPATTS and IMPATTS to match across octives. We need a theory for UHF surface wave networks as well as for reactance matching of multioctive bandwidths. The schools could relate some of these problems within the framework of distributed parameter networks. The educated network theorist will become the systems engineer and education might take this more into account.

32. A. Zverev: Of most interest in the area of new components will be materials, eg. rutile cubes or squares could become revolutionary. For this we are lacking a component technology while the reporting of research could be more usefully channeled to those to whom it could be significant.

33. H. Rapp: It is necessary to improve upon the concept of optimality giving a solid definition of what is optimal. Perhaps this is best done in terms of probabilities. For optimization we need synthesis techniques for initial networks and statistical theories for carrying out optimizations. Tools are needed for the design of whole systems.

34. H. Haertl: The status of LSI by computer aided design for a whole system needs clarification. The use of the computer for an initial set-up and then optimization is an expensive proposition.

35. S. Darlington: Practical designs carry too many cost functionals for efficient optimization. Up to a point minimizing cost is okay but there are many value judgements, it is hard to balance things such as reliabilities, and the results are no better than the models used.

36. A. Zverev: Although optical filtering problems can be projected upon two dimensions they are basically three dimensional. To date optics have been more in the hands of physicists than engineers but this along with acoustical filtering (which can be cheap and elegant) is a youthful field. Similarly for display networks. In general these topics are lagging in development and are very appropriate for university research.

37. L. Weinberg: Richards' transformations are available for application to picture data processing as are the concepts of filtering with transmission-lines for optical systems. Seismic and two-dimensional digital filtering is presently in the hands of those unfamilier with the ideas of network theory where multivariable theory is applicable (and should be taught more). Some of our future problems, especially if LSI gathers momentum for filter networks may be in mixed lumped-distributed systems, and here is where a knowledge of lumped-parameter filter theory would be basic for extending the results to two variables. Also, the two-variable and multivariable work would be useful for multidimension digital filtering. It is as yet unknown how to approximate appropriately with multivariable functions. It would be profitable to bring people in some of these areas into network theory conferences and vice versa.

The topics were then turned to means of building up background in future areas and communication between groups.

38. O. Alekseyev: Almost all Russian concepts are in translated form. Also one can learn Russian, attend conferences in East Europe, etc.. Most Russian radio engineers can be contacted through the Popov Society.

39. S. Darlington: As technology changes it will be those who have solid basic backgrounds who will survive.

40. K. Zaki: Industries seem to need to show some initiative in contacting universities.

41. J. Skwirzynski: Perhaps summer hiring will be a way of doing this in the future.

42. S. Darlington: The hiring by universities of retired industrial personnel could be attractive in maintaining industrial-university liaison.

43. A Zverev: All seem agreed that better contacts are needed; this meeting is certainly a step in that direction.

44. K. Zaki: Perhaps NSF could support university-industry interchanges say be contracts between industry and university for students to participate in both aspects.

III Results of the NSF - Attendee Questionnaire

In this section we present in table form and without further interpretation the results of the questionnaire, the latter being given in appendix c). Included in this, at the end of the section is the resultant bibliography which is directed and referred to by [ ] in the tables which precede it.

a) Tables

TABLE 2

Fields of Significant Problems in Filter Theory as Rated by 14 Participants

Fields	Average Rank	# Voting 1 (and 2)
Digital Filters	3.0	5(1)
Approximation Theory	3.8	1(5)
Active RC Circuitry	4.3	1(0)
Time-Domain and Matched Filters	4.8	2(1)
Realization Techniques	5.0	2(0)
Microwave Filters	5.2	0(2)
Crystal and Ceramic Filters	6.1	0(0)
Phase-Lock Filters	8.0	0(0)
Distributed RC Filters	8.1	0(0)

Other Areas of Importance Mentioned

Fields	# of Votes	Ranks (N = No. Ranking)
Mixed Lumped Distributed Systems Realization	2	3, N
Switched Filters	1	2
Mechanical Filters	2	3, 2
Signal-Structure parametric filters	1	N
Multiport Filters	1	N
Integration of Active RC or RC distributed filters	2	2, 2
N-path or other time-varying filter circuits	1	5
Optimization Techniques	1	9
Filters for LSI and IC	1	3
Transversal Filters	1	4
Optimal, Tracking, Kalman filters	1	5
Biomedical Filtering	2	1, 1
Sophisticated Data Processing Applications	1	3

TABLE 3

List of Problems on Which Research Is Needed and Background Necessary

	Problem	Background; see bibliography for [ ] entries
I	<u>Digital Filters</u>:	
a	Digital Filters: structures and quantization effects.	[26]
b	Development of "Optimal" Filters for digital and hybrid modulation systems.	[23]
c	Cheap integrated A-D and D-A converters for use with digital filters.	
d	Optimization of Computation Programs for digital filters.	
I	<u>Approximation Theory</u>:	
	Approximation of Computer to approximations and realizations for high reliable miniaturized filters.	Mathematical Programming Techniques Numerical Analysis Matrix Manipulation [11, 33, 80, 98, 101]
b	Approximation theory to take into account tolerances and reliability of components.	[9, 59, 95]
c	Approximation Procedures for lumped distributed filters	[48]
	Approximation Procedures for functions of two complex variables and for quotient of sums of Exponential Polynomials whose coefficients are real polynomials.	Two Variable Function Theory. Koga's papers in 2-variable functions
e	The use of approximation theory in the design of crystal and ceramic filters.	Theory of Approximation Numerical Analysis and Programming
	<u>RC Active Filters</u>:	
	Active Circuit Filters at 100 KHz and higher.	
b	Design of Active Filters using identical active RC resonator blocks within a topological structure such that specified functional coefficients are determined by simple resistor-matrix adjustments.	Active Filter Synthesis and Design Network and Filter Theory. [32, 95]
c	IC realization of active RC filters and gyrators.	[29, 55, 65]
	Combination of Active and Crystal Filters to obtain versatility of active filters and frequency stability of crystals.	Materials Network and Filter Theory [31]

Table 3 con' d

V	<u>Time-Domain Filters</u>:	
a	Synthesis for Criteria Specified in the time domain (intersymbol interference; zero crossing distortion).	Advanced Maths Communication Theory Unpublished papers at Bell Telephone Labs. known to the author of [59-62]
b	Time-domain filters in data transmission systems.	Fast-Fourier Transformation Techniques [33, 80, 97, 101]
V	<u>Realization Techniques</u>:	
a	Realization Techniques under given structural constraints.	[8]
b	Design methods for RC n-ports	[8]
c	Multiport Filters	[49, 66]
d	Design of Lossy filter with low sensitivity	[106]
e	Synthesis procedures with practical configurations of two-variable system functions.	Two-Variable function theory [104]
f	Positive Real functions of two or more complex variables (effective tests of these positive real functions).	
g	Lumped-Distributed Filters	[1, 52]
VI	<u>Microwave Filters</u>:	
a	Microwave Filter Synthesis Techniques	[15]
b	Surface Wave Filters	[87, 92]
II	<u>Crystal Filters</u>:	
a	Application of "unified non-minimum" phase filter design methods to crystal filters	[76]
I	<u>Mechanical Filters</u>:	
a	Synthesis Methods for Mechanical Filters	[10, 45]

Table 3 con'd.

	Miscellaneous:	
a	Signal Structure Parametric Filters	[105]
b	Layout Design for Large Integrated Circuit Filters.	[37, 70, 99, 100]
c	N-Path and other time-varying filter circuits	
d	Electronically Tunable Circuits	[16]
e	Simultaneous optimization of Phase and Magnitude for large bandwidths.	[30]
f	Synthesis algorithms and realization methods for multi-pass band filters.	[18] Optimization Techniques
g	Adaptive Filtering especially for biological control.	unaware of papers

TABLE 4

Background Needed for Study of Some Filter Theory Areas

	Major Areas in Filter Theory (In Alphabetical Order)	Background
I	Active RC Circuitry	[2, 12, 22, 40, 41, 58]
	----- using gyrators	[57, 93]
	----- compatible with industrial production capabilities	[61, 83] Calculus, Matrix Theory, State-Variables, Numerical Methods for Computer Aided Design, Materials (IC Technology, Crystals)
I	Approximation Theory:	
	----- in the synthesis of passive filters	[19, 24, 30, 58, 74, 85, 86]
I	Computer Applications to Filter Design	[6, 9, 11, 33, 59, 88, 89, 97, 98, 102] Graph Theory, Matrix Analysis Linear Programming, Optimization Technique, Complex Function Theory
	----- Computer Aided layout of hybrid RC Circuits	[61, 63, 68, 83, 94]
V	Digital Filters	[20, 21, 25, 26, 34, 35]
V	Lumped-Distributed Systems	[38, 42, 43, 44, 71, 73, 75, 77, 79, 95, 104] Richard's Papers
VI	Microwave Filters and Acoustics and Charge Transfer Devices	[1, 13, 14, 16, 17, 27, 36, 52, 53, 56, 60, 69, 78, 87, 89, 92] Solid-State Physics, semiconductor devices, differential equations Z-transform, microwave acoustics piezoelectric elastics.
II	Network Theory	[3, 8, 66, 99, 100]
	----- Sensitivity Theory	[39, 50, 64, 96]
	----- Optimal Filters for FSK, PSK, PAPM	[7, 18, 46, 76, 88, 106, 108]
	Optimization methods for filter specifications in time-domain and optimization of filters by resistivity minimization	Crystal Filter Theory and adaption to monolithic structures , Optimization of active filters with resistivity minimization, Optimization Techniques.
III	Realization Techniques	[67]
	----- Time Variable Networks	[90]
	----- Realization Techniques for impedance transformation	[54, 69, 81]

TABLE 5

List of Organizations Active in Filter Theory (In Alphabetical Order)

Industrial Organizations	
1.	AEG - Telefunken (W. Germany)
2.	Bell Laboratories
3.	Comsat Laboratories
4.	I T & T
5.	Lenkhurt Electric Co.
6.	Marconi Research Lab.
7.	MBLE Research Lab.
8.	Nippon Electric (Japan)
9.	Nippon Telephone and Telegraph (Japan)
10.	Philips (Netherlands)
11.	Siemens and Halske (W. Germany)
12.	Societe Anonyme de Telecommunications, Paris (France)
13.	Westinghouse (ATL)
University Organizations	
1.	City College of New York
2.	Cornell University
3.	Leningrad Electrical Engineering Institute of Communications (USSR)
4.	Moscow Power Institute (USSR)
5.	New York University
6.	Odessa Electrical Engineering Institute of Communications (USSR)
7.	Polytechnic Institute of Brooklyn
8.	Ruhr-University, Bochum, (W. Germany)
9.	Stanford University
10.	Syracuse University
11.	Techn. University Munchen (W. Germany)
12.	Tokyo Institute of Technology, (Japan)
13.	Tokyo University (Japan)
14.	U. C. L. A.
15.	Universitat Erlangen (W. Germany)
16.	University of Maryland

TABLE 6

List of Suggestions for Strengthening Filter Theory

1. Special Journal on Filter Theory and Design.
2. International meeting of filter experts on a regular basis, dealing with filter problems in a wider sense.
3. Installment of Committees and documentation centers concerning filters.
4. Establish Post-Doctoral Fellowships in conjunction with Industry.
5. Summer Support in Industry of Students.
6. Joint Industry-University Projects.
7. Communication between University and Industrial Organizations.
8. Present more tutorial papers that relate theory to practice and make better theory simple.
9. Original papers should mention practical applications of the theory.
10. Point out the usefulness of filter theory to other fields.
11. Improve communications between specialists on communication filters and on data processing filtering.
12. Improve communications between system theory specialists and solid-state circuits specialists.

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IV. Cooperation with the International Symposium on Circuit Theory

By the medium of goodwill an arrangement of cooperation was worked out between the organizers of the International Symposium on Circuit Theory and the International Filter Symposium. This had the effect of moving the latter from the University of Maryland to UCLA and eventually Santa Monica such that attendees of one meeting could easily attend the other, as they were set back to back timewise. We feel that in the long run the results proved beneficial especially to the International Symposium on Circuit Theory which received a good share of its key participants through travel and assistance rendered by the International Filter Symposium. What the results do show is that there is an unmet need for Symposia on rapidly developing specialized areas where a bridge between theory and practice can be formulated and the future orientation of the field developed.

V. Comments on Filter Theory in Hungary and Nigeria

Following the IFS Professor Newcomb visited Nigeria and Hungary where he had occasion to discuss filter theory within the framework of the two countries. Some comments on this seem in order.

In Nigeria, and Central Africa generally, there are problems peculair to a large land mass in the tropics. Consequently besides the problem of packaging filters to avoid deterioration due to the climate, there is a need for some type of adaptive filtering to compensate for large momentary changes in communication channels. Because the economy will also be geared to the introduction of new power generating stations, the need for economical filtering at high voltages and low frequencies is great. For such filters, perhaps to achieve good load regulation, studies at Maryland have shown that very few solid results are available.

Because of its significance to new classes of lumped-distributed filters the paper of Dr. P. Dewilde, of the University of Lagos, was one of wide interest to the IFS attendees; he plans to continue this work sometime in the near future. Most likely he will attend the Operator Theory of Networks Symposium, University of Maryland, October 1972, where his ideas on filter theory will be further discussed in the abstract context. Perhaps during that trip he can interact with some filter practioners.

In Hungary, too, considerable work in the filter area is being carried out, under Drs. A. Csurgay and A. Baranyi at the Research Institute for Telecommunication (TKI), and Dr. K. Geher at the Technical University, both in Budapest. At the TKI there are about ten high level researchers working in the area, concentrating efforts on nonlinear, microwave, and lumped-distributed filters while at the Technical University about four people are concentrating efforts on filter tolerances and sensitivity. The TKI has an excellent movie depicting some of their filter related activities which would prove profitable to show at meetings like the IFS.

In the future it is suggested that continued efforts be made to attract people from developing and Eastern countries to meetings such as the IFS, this because their viewpoints and particular problems are often different and certainly challenging.

VI. Future Plans

In terms of concentration of attendance, intensity of interaction, accomplishment of the objectives and enhancement of a unification spirit among filter engineers the Symposium was an unqualified success. Consequently, a future planning dinner was held by P. Geffe, N. Levan, J. Miller, R. Newcomb, and W. Spencer on Monday night April 17, 1972. At this it was decided to plan another International Filter Symposium in three to five years, depending upon rapidity of developments, with coordination through present University of Maryland personnel and the added involvement of Dr. J. Miller.

APPENDIX a)

CALL FOR PAPERS

INTERNATIONAL FILTER SYMPOSIUM

Sponsorship Committee:

V. Belevitch (Belgium)

J. Bingham (USA)

J. Colin (France)

S. Darlington (USA)

C. Desoer (USA)

A. Fettweis (West Ger.)

T. Fujisawa (Japan)

J. Kaiser (USA)

J. Orchard (USA)

R. Saal (West Ger.)

J. Skwirzinski (England)

G. Szentirmai (USA)

B. Temes (USA)

E. Ulbrich (West Ger.)

H. Watanabe (Japan)

L. Weinberg (USA)

A. Zverev (USA)

N. DeClaris, Host

An international symposium on electric wave filters will be held at the Miramar Hotel, Santa Monica, California, April 15-18, 1972. Papers on all subjects pertaining to electrical filters are invited. Suitable topics are: approximation theory, realization techniques, digital filters, microwave filters, active RC circuitry, gyrators, crystal filters, surface wave techniques, time-domain and matched filters, phase lock circuits, distributed RC filters, and unconventional filters. Original contributions are wanted, but review and tutorial papers will be considered.

To receive a final copy of the program, contact the program chairman at the address below.

INSTRUCTIONS FOR AUTHORS: Authors should submit a two-page summary of their paper including references by Jan. 15, 1972, to

W. J. Spencer, Program Chairman
Bell Telephone Laboratories
555 Union Boulevard
Allentown, Pennsylvania 18103

Authors will be notified of acceptance by February 15. Accepted summaries will be published in a Proceedings available at the meeting.

The International Filter Symposium has been organized by:

Philip R. Geffe, Co-Chairman
Westinghouse Electric Corp.
Baltimore, Maryland 21203
Phone: 301-765-3781

Robert W. Newcomb, Co-Chairman
University of Maryland
College Park, Maryland 20742
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APPENDIX c)

IFS - NSF Attendee

Questionnaire

1. I feel the significant problems in Filter Theory lie in the following fields. (Please rank in order of importance):

a. _____ Approximation Theory
b. _____ Digital Filters
c. _____ Microwave Filters
d. _____ Active RC Circuitry
e. _____ Crystal and Ceramic Filters
f. _____ Realization Techniques
g. _____ Time-domain and matched filters
h. _____ Phase-lock Filters
i. _____ Distributed RC Filters

Others (specify)

j. _____
k. _____

2. Three specific filter problems upon which research is needed in the next five years are:

(1)

(2)

(3)

3. What is/are your major field(s) of study?

(1)

(2)

(3)

4. List a bibliography (6, or more if necessary) which identify with the major recent results in your field(s) of Filter theory.

(1)

(2)

(3)

(4)

(5)

(6)

5. What background is needed to work with the main new ideas in Filter Theory

(a) as pointed out in question 2. (The numbers used below are the same as in question 2).

No. as in Q. 2	Background Papers (No. as in Q. 4 if applicable)	Others: as Maths, Materials, etc.	Field (letter as in Q. 1)
1.			
2.			
3.			

(b) as pointed out in Question 4

No. as Q. 4	Background Papers (No. as in Q. 4 if applicable)	Others: as Maths, Materials, etc.	Field (letter as in Q. 1)
1.			
2.			
3.			

4.		
5.		
6.		

6. Identify 6 major organizations (including University and Industrial organizations) and order them according to their capabilities in Filter Theory.

	(Check appropriate box) University	Industry
1.		
2.		
3.		
4.		
5.		
6.		

7. In what way can we strengthen the field of Filter Theory? (Concerning organization, communication among Filter theorists, etc.).

4/15/72

APPENDIX d)

1. Objectives

In order to strengthen the Symposium through establishing a set of accomplishments as suggested by NSF, the Symposium organizers wish to set the following objectives:

1. Delineation of the major recent results in and status of the filter field.
2. Identification of important unsolved problems and establishment of priorities for them.
3. Identification of organizations and their capabilities in the filter field on a world wide basis.
4. Delineation of background needed to work with the main new ideas and results in the filter field.

To realize these objectives a special session "Current and Future Filter Status" is set up for Tuesday morning, April 17, this following the special session on "International Filter Survey" scheduled for Monday night, April 16. The latter session will consist of talks by distinguised invited speakers covering Europe, Japan, the USSR and the USA followed by open discussion. The former session will be an open workshop type forum covering the four objectives mentioned above consisting at least of a panel of participants traveling on NSF Symposium funds. In essence the session "Current and Future Filter Status" will elaborate through a broad spectrum of participants, and with reference to the above four objectives, the material brought forward in the session "International Filter Survey."

A report covering these results of the Symposium will be issued by the University of Maryland in early August and participants at the meeting are encouraged to contribute ideas to Professor Newcomb or the NSF Research Assistant C. Kulkarni for consideration in the report. Included in the report, which will be reviewed by the Co-Chairman and Program Chairman, will be a directed bibliography. Recommendations will also be made as to follow up procedures such that the information obtained can be periodically updated.

2. Organizers

The primary organization for the Symposium has been in the following hands:

1. Program Chairman: William J. Spencer
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555 Union Boulevard
Allentown, Pennsylvania 18103

2. Co-Chairmen:

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APPENDIX f)

1. Review of Filters in Japan, Lecture Notes, Dr. H. Watanabe, Nippon Electric

After the complete destruction of World War II, reconstruction of communication systems in Japan has made rapid progress. Slide 1 shows how rapidly grew up the number of Telephone Subscribers. At present, the total number of subscribers is more than 20 million, and it can be said that approximately 1/10 of this number, 2 million, is the number of installed channel filters. As far as the number of channel filters is concerned, Japan is the second in the world.

For lack of natural resources, including quartz crystels in Japan, L-C filters have been traditionally used. So, research on magnetic materials has been made remarkably, and, as a result, extremely high quality ferrite materials such as Neferite and Super Neferite were invented and have been manufactured. Slide 2 shows the history of the development of inductors utilized in channel filters.

Before 1955, Ferro-Oxide materials (Sen-Dust) were used T-Type 24 ch/Eq.

1955 Mn-Zn Ferrite were first used. S-Type 24 ch/Eq., U-Type 48 ch/Eq.

1958 Neferrite were used 60 ch→120 ch→(BS Type)→300 ch/Eq.

1966 Neferrite

Neferrite, the registered name of a magnetic material invented by Nippon Electric in 1958, is a Mn-Zn ferrite modified by CaO and S_iO_2 and has high quality:

$$\tan\delta/\mu = 1.5 \times 10^{-6} \text{ at } 100 \text{ kHz}$$

Super Neferrite was invented in 1969, and has hysteresis loss, temperature stability, disaccommodation factors all remarkably improved.

$$\tan\delta/\mu = 0.8 \times 10^{-6} \text{ at } 100 \text{ kHz}$$

This makes it possible to minimize filters.

On the other hand, improvements of filter design methods and application of computers have also been made strongly. Slide 2 shows the first computer that was designed and has been exclusively used for filter design problems. This computer is still used for various kinds of network design, while some designs are made with larger more modern computers as well, as shown in Slide 2. As consequence of the development of ferrite and design techniques, the volume of channel filters became smaller and smaller as shown in Slide 3, Slide 4 and Slide 5.

Using these filters, the channel translating unit was miniaturized time by time.

Slide 6 shows 24 ch/Bay 1955 Vacuum Tube Mm-Zm

Slide 7 shows 48 ch/Bay 1958 Vacuum Tube Mm-Zm

Slide 8 shows 120 ch/Bay 1958 Transistor Neferrite

Slide 9 shows 300 ch/Bay 1966 Transistor Neferrite

Slide 10 shows the currently used translating unit, where two channel filters are mounted. Attenuation vs frequency characteristics of these channel filters are shown in Slide 11 and Slide 12. Characteristics in the pass-band satisfy within 1/20 of CCITT's recommendation.

≪ within 0. 4 db at 300 KHz ≫

As applications of the computer became possible, filter design theory had developed rapidly, and many new types of filters such as quasi-Chebychev filters, Chebychev filters with flat group delay and Chebychev filters with many pass-bands have been designed and manufactured.

Slide 13 shows a flat group delay channel translating unit which is utilized for data transmissions as well as telephone transmissions.

Slide 14^{I} shows the circuit configuration of a flat delay channel filter.

Slide 14^{II} shows the over-all characteristics of a flat delay channel filter.

Slide 14 shows a so called "Parametric filter" or more excatly a quasi-Chebychev band-pass filter, which realizes a circuit with a minimum number of inductors required to meet the specifications. In this particular example, there are 6 inductors while the order of circuit complexity is 13.

Network optimization techniques have also been investigated throughly and the most general Chebychev approximation method was developed. In this method an optimization problem is regarded as a constrained mathematical programming problem and this problem is locally linearized at a feasible solution and is solved as a linear programming problem. It is proven that the maximum error becomes smaller at each iteration of this procedure. Therefore, we can get the minimum of the maximum error by these iterations.

As an example of the approximation by this method, Slide 15 shows the design results of a cable building-out network that approximates standard coaxial cable characteristics within $\pm$ 0. 01 dB.

Slide 16 shows another example in which delay characteristics of a through group of filters (60-108 KHz) are equalized with $\pm$ o. 27μ's at 550μs. These filters are used for high speed data transmission or newspaper facsimile transmissions.

Slide 17 shows an example of the exact design of a vestigial side-band filter with equalized delay after homodyne detection.

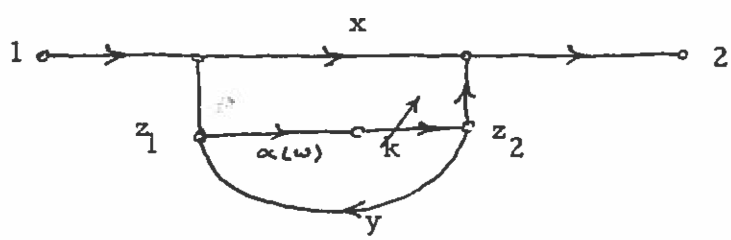
As to wave-separation, design of a three-port wave separator without the use of susceptance-compensating-network was established.

A four-port directional filter which is applied to a submarine repeater system has also been developed without using any susceptance compensating networks.

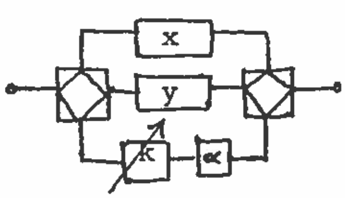
Slide 18 shows the network configuration of a directional filter which has been applied to 12 MHz submarine repeater systems. Characteristics of this filter are shown on Slide 19. As Japan is an island country, development of submarine repeater systems have been made long. This design technique has been applied to a 30 MHz submarine system with 2, 700 ch links as shown in Slide 20.

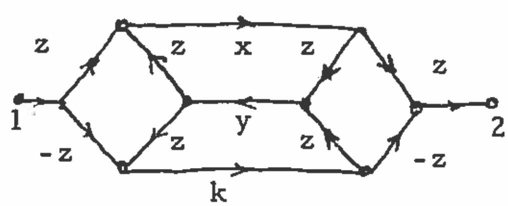
As to variable equalizers a new principle was proposed and applied in practice for a mop-up equalizer in a long-line repeating system.

Slide 21 indicates an example of new types of variable equalizers. The principle is essentially based on that of feedback systems:



$$\text{if } z_1 z_2 = 2xy \quad \text{then} \quad S_{12} = \frac{1 + k\,y}{1 - k\,y}$$





$$S_{12} = \frac{4z^2 x}{1+\sqrt{5}} \quad \frac{1 + \frac{\sqrt{5}-2}{x}\,k}{1 - \frac{\sqrt{5}-2}{x}\,k}$$

This is the 4th type of Variable Equalizer.

Owing to the improvement of piezoelectric ceramics, electro-mechanical filters have been applied to narrow band-filters in the relatively low frequency region (up to 50 KHz), where electro-mechanical filters are smaller in size and cost, and more reliable than conventional inductor-capacitor filters.

Slide 22 shows a dial signal receiving filter in use in standard channel translating equipment since 1965; up to now about 500,000 filters are installed. Comparing with conventional LC types this reduces 1/3 in volume (20cc) and is wider in the pass-band with higher attenuation in the stop-bands. This filter consists of 2 bending resonators coupled torsionally, 2 coils and 2 SF capacitors. Center frequencies are 15.838 KHz, 19.838 KHz and 23.838 KHz. Slide 23 shows an equivalent circuit and Slide 23[1] shows the charcteristics.

Slide 24 shows reed filters utilized ina raging system operated by NTTPC. Each pocket Bell receiver has 4 different reed-filters that specify the number of the subscriber. This type of filter has been manufactured in more than 500,000 units. Center frequencies are 44 different frequencies between 502.5 Hz and 1147.5 Hz with 15 Hz span.

Old Size = 7 x 8 x 38 = 2.1cc

New Size = 6.5 x 5 x 19 = 0.62cc

Slide 25 shows typical characteristics of reed filters.

Slide 26 shows a conventional symmetrical lattice structure which is widely used because of simplicity, and ease of realization. But it has a strong restriction, that is the characteristic function must be an odd function of s.

According to Cauer's reactance theorem, we can realize any reactance 2-port in partial fraction expansion form. This structure is practically realized by means of a mechanical resonator with two piezoelectric ceramics equivalent to an ideal transformer.

Slide 27 shows a telegraph channel filter with Chebychev delay type, whose characteristic function is not an odd function, but some other polynomials of s.

Center frequencies are between 420 Hz and 3180 Hz, 24 frequencies with 120 Hz span.

Slide 28 shows typical characteristics.

Slide 29 shows an active filter configuration with high selectivity composed of positive and negative feedback. This active filter was used in the earth command receiver of the Japanese Scientific Satellite-I "SHINSEI" where a small and light filter with high stability and reliability is required.

In my present talk, I only refer to filters mainly produced in the carrier transmission communication industry, though there are many other filters utilized in the consumer industry, defence agencies, special filters in laboratory use, etc..

In Japan, there are many engineers who have studied circuit theory many years, and therefore, filter design itself has also been widely investigated. I am afraid that I missed some other important activities such as microwave filters, distribution, etc..

Note:

A number of the slides mentioned can be found as figures in the main reference: H. Watanabe, "Computer Applications in Circuit Design," NEL Research and Development, No. 20, January 1971, pp. 110-122.

APPENDIX f)

2. Review of Filters in the USSR, Prof. O. Alekseyev, Leningrad Electrical Engineering Institute, Leningrad, U.S.S.R.

Despite the long history of development of filter theory and implementation, there are many unsolved problems not only in relatively new areas of the filter theory and technique, such as digital, active, lumped-distributed, signal-structure parametric filters, but also in classical passive L-C-R and R-C filters. New requirements of electrical systems and equipment, the rapid development of technological methods of implementation encourage engineers and researchers to seek new improved realizations of different kinds of filters. Those problems have received a great deal of attention in the U.S.S.R.. It is impossible within the framework of a short survey to cover all aspects of filter theory and practice and to review all important results which were obtained recently by Soviet specialists. Therefore, this survey is based only on some results which were published in the period 1968-1971 in Soviet magazines which are available in the U.S.A. in English translation and embraces some results in the theory and design of traditional L-C-R and R-C filters, active filters, distributed filtering structures and so-called signal structure parametric filters.

Filters used in modern equipment have to meet a variety of stringent conditions. A large amount of computational work is required to design filters to satisfy these conditions. Many practical problems which had not been solved with the advent of computers. The main feature of works devoted to computer-aided filter design is the use of the Chebyshev criterion for optimization and the treatment of the approximation problem as a typical problem in linear programming.

Ye. I. Baskov [6] described some methods for using the computer in the main stages in low-pass L-C-R filter design with given effective parameters. The central point of this work is the approximation problem which is formulated in terms of a system of linear inequalities which can be solved by the simplex method.

As is well-known, losses in L-C-R filter elements lead to strong distortion of responses. Compensation of those losses by the use of active elements, for example tunnel diodes [4], has some disadvantages and has not found a wide application. In the paper by Ye. I. Baskov and A. T. Lebedev [27] a method for optimizing the attenuation responses of filters using components with given inhomogenious losses is described. This paper outlines a new interactive method for optimizing such filters. The essence of the method lies in approximating the nonlinear problem by a sequence of linear problems which can be solved by the extremely effective and well developed methods of linear programming. By this means the authors found the filter component values for which the variation of the attenuation response over the pass-band is below a given level, while the minimum values of the guaranteed attenuation in the suppression band is maximized. Although the authors did not compare their method with those given by other authors, their experimental results show the high efficiency of the algorithm with regard to the final response and solution time.

In a number of cases low-pass ladder filters are very convenient for use even in the case of band-pass filtering problems. In such cases a filter is called a low-pass filter with limited pass-band. For that case the suppression of a signal in the stop-band can be essentially improved at the expense of a change of attenuation for the first unused part of the pass-band. S. Ye. London and G. S. Lipchin [3] solved the approximation problem for such a case with the use of a computer and gave tables of the computational results. Those filters are recommended by the authors for example as the effective means to provide a required suppression of harmonics in modern radio transmitters. The following advantages of such filters are pointed out: high impedance level with limiting capacitances, small power losses, better numerical values for realization of filter components. A similar problem was solved by I. N. Teplyuk [32] for active R-C filters.

It is well-known that the achievement of performance figures of filters promised by the theory depends strongly on many factors such as real frequency band, power level, numerical element values, etc.. A number of recent papers [1, 13, 16, 17, 23, 24, 31, 34, 36, 37, 41] are devoted to the realization problem, the optimization with respect to certain characteristics, and detailed consideration and comparison of different possible realizations of filters. Ya. A. Sobenin and S. A. Frolov in their paper [15] discussed the possibility of utilizing the sensitivity for analyzing the accuracy of a polynomial filter attenuation curve. The authors proposed general parameters for estimating the effect of component errors on attenuation accuracy and described some methods for improving attenuation stability.

The synthesis of electrical filters containing no inductance component recently raised issues of increasingly great interest. Two trends can be distinguished in the evolution of methods for designing such networks; namely, methods concerned with the synthesis of passive R-C networks and methods for active R-C networks.

For a long time one of the unsolved problems in passive R-C networks remained that of constructing an optimal transmission function for R-C filters [42]. The paper [8] by A. A. Lanne and V. T. Snegirev is concerned with this problem. The transmission function for which optimization according to a given criterion involves the use of all its variable parameters is implied by the authors as the optimal transmission function. They proposed the so-called "method of zones" for solving the Chebyshev approximation problem for passive R-C filters. This method amounts essentially to expressing a set of linear inequalities for the roots of a denominator of the transfer function of a filter to be real and negative. The method of zones can be formulated as a linear programming problem. The authors proved a theorem which shows that the optimal transmission function of a passive R-C filter must have a multiple pole whose multiplicity is equal to the degree of the denominator polynomial. From this theorem a number of particular problems of Chebyshev approximation were solved for different values of the multiple zero and it was shown how to find the value of zero corresponding to a global minimum of the approximation error.

An important trend in the R-C circuitry is the use of distributed R-C structures. Their use in filtering and pulsed networks enable one not only to implement networks by microelectronics technology, to reduce the nember of passive elements and the area occupied by the network, but also to improve performance. Recent publications on this topic are devoted primarily to theoretical and experimental investigations of properties of different versions of such structures.

Since exact calculation of distributed R-C structures are difficult, it is of a great interest to develop approximate methods for analyzing their responses. V. V. Galitskiy and G. V. Petrov considered equivalent L-, and T- sections and their parameters for approximating uniform and nonuniform distributed structures of various configurations [12]. Transient responses obtained by means of the equivalent circuits are compared with the exact transient. It is shown that the - equivalent circuit is best adapted for calculating the transients approximately. A. S. Vasil'yev and V. V. Galitskiy [21] gave a procedure for obtaining A-matrices of uniform distributed structures and considered the properties of these matrices. The recurrence expressions obtained are convenient for computer programming of such R-C structures and of circuits using them.

The size of districuted R-C filters can be reduced by constructing them in the form of a large number of resistive layers separated by thin dielectric films. In the paper [26] V. Ye. Prozorovskiy derived general formulas describing the potential distribution in such a structure. Unlike previous works on this subject he obtained expressions in closed form and their calculation can be reduced to operations with a finite number of terms. On the basis of this theory, the frequency and transient responses of multilayer distributed R-C structures are analyzed. In another paper [11] V. Ye. Prozorovskiy and D. N. Negodenko analyzed the amplitude-frequency and phase-frequency characteristics of a five-layer thin-film rejection filter.

The papers [22, 39] by G. V. Petrov consider the transient response of uniform and nonuniform distributed R-C structures and analyze the effects of structure parameters upon the response. In particular the author considered so-called R-C-M-C-NR structures with a central metal layer which enable essentially new circuits to be designed [39].

V. V. Rudnev, I. I. Goryanina and N. G. Nifontov in their work [45] noticed that leakage conductance of the R-C distributed structure substantially changes the electrical characteristics of filters. In connection with this, they calculated R-C distributed structure filters with leakage conductance taken into account.

The possibilities of using passive R-C networks as electrical filters are limited since in practical problems the required order of the approximating functions for achieving a given accuracy in reproducing the specified characteristics is, as a rule, very high. As regards reproducing accuracy, active R-C networks have the same potentialities as passive L-C-R networks - that is why active R-C filter synthesis is that of obtaining a circuit realizing a transmission function given by the ratio of two polynomials with real coefficients. There are several known active components which can be used in such filters - a gyrator, a negative impedance converter or an amplifier. The use of active filters in equipment is mainly inhibited by the relatively low stability of frequency responses which are especially sensitive to variations in the parameters of the active components. A number of papers recently published in the U.S.S.R. considered different possible realizations and their sensitivity and stability.

Yu. P. Galyamichev and N. S. Nikoloyenko presented results on the synthesis of active R-C filters and delay lines based on negative immitance converters with the aim of achieving minimum sensitivity of the transmission function poles [7]. These results are given in the form of tables of values of normalized components and of the sensitivities of the modulus and argument characteristics to individual passive components, to the conversion coefficients and to the overall sets of components. It was found that the mean square sensitivity of filters of the sixth order is so large that only a Butterworth filter can be implemented in practive. In the paper [14] the same authors described a method for synthesizing converter R-C networks by expanding the transmission function into prime factors and realizing each factor by separate converter R-C sections. Practically realizable Butterworth and Chebyshev filters and delay lines, up to eighth order, can be synthesized by this method. The tables of synthesized filters are given.

D. A. Tsizelson [35] discussed the main parameters of gyrators as active components for R-C filters and evaluated the sensitivities of the pole qualities ("Q" factor) of a selective gyrator network. On the basis of that consideration, the author affirms that "a gyrator is one of the most hopeful components for realization of active networks without coils and transformers in integrated implementation".

Taking frequency response stability as the criterion for practical application of a given active component of R-C filters, G. L. Khazanov examined circuits with active components of different types [9]. The author does not recommend the use of a negative impedance converter in active R-C filters because of high instability and came to the conclusion that a selective amplifier and gyrator can be regarded as equally satisfactory. On the basis of his examination, the author recommends the following sequence for synthesizing a multisection R-C filter realizing a transmission function with several pairs of complex conjugate poles. Namely, the use of gyrators is recommended for cases when the "Q" factor of a pole less than or equal to 3 and $Q > 15-20$. When Q factor lies within the interval 3 - 15, each pair of poles should be realized by a selective amplifier circuit.

In order to improve the stability of active R-C filters G. L. Khazanov in his other paper [30] proposed that the high-Q second order section be replaced by sections with transfer function poles of relatively low Q in such a way that the frequency response of the initial high-Q section transfer function is approximated to a given accuracy.

A number of papers by A. Ye. Znamenskiy are devoted to some practical problems of the design of active R-C filters. The paper [99] gives a method for compiling tables for the design of active R-C filters with the aid of Chebyshev fractions. In [10] and also in the paper [33] by I. S. Kislyakov the influence of the input impedance and the capacitor losses on the active R-C filter response are examined. To avoid the resulting errors the know predistortion method was used.

M. Z. Chapovskiy and V. N. Loveyko [43] pointed out that in some cases good results with respect to sensitivity and stability of active filter responses can be obtained by the use of amplifiers with common base transistors. In the correspondence [46] they presented the results of an investigation of the class of active R-C circuits in which the presence of resistors in the electrode circuits exhibit a number of interesting properties.

A. F. Beletskiy, A. A. Lanne and V. T. Shegirev [38] noted some of the disadvantages of active R-C filters and introduced the class of R-C filters which they called combined R-C filters. To that class they asribe active R-C networks whose transfer functions contain a portion of the maximum possible number of complex-conjugate poles. The authors solved the problem of optimal synthesis of such filters for transfer functions having a single pair of complex-conjugate poles and showed that these filters combine the high efficiency of approximation and relatively high stability of the frequency response. This paper also presents a solution to the problem of synthesizing combined R-C filters having a specified Q factor for each complex-conjugate pair of poles. The approach described in [38] was apparently one of the first attempts to solve the problem of reducing the sensitivity of network characteristics at the approximation stage.

High-selectivity filters using electromechanical systems is a very important area. The theory and design of such filters with the use of piezoelectric crystals was generalized and developed in the book [48] by Ya. I. Velikin, Z. Ya. Gel'mont and E. V. Zelyakh. Some new results in this area are given in the papers [19, 28].

In wide-band communication channels the use of crystal band-elimination filters is limited by the undersirable attenuation humps that occur in their passbands. The basic reason for these is that a crystal resonator has several supplementary resonances, in addition to its main resonance. E. V. Zelyakh and V. D. Krukhmaleva [19] consider the crystal band elimination filter circuit in which the effects of supplementary resonances close to the main resonance may be compensated. The proposed circuit is obtained by shunting two four-terminal networks. The theory indicating that the effect of one supplementary resonance of the piezoelectric resonator on the attenuation curve can be completely compensated was proven experimentally.

Ya. I. Velikin, Z. Ya. Gel'mont, E. V. Zelyakh and A. I. Ivanova in their paper [28] discussed the design of low-pass and high-pass magnetostrictive filters based on ladder circuits, and of band-pass filters obtained by cascade connection. The authors derived expressions for the filter components and quoted some experimental results. The authors developed special screened resonators to avoid mutual influence between resonators at a filter.

The use of the structural properties of signals opens up novel possibilities of both theoretical and practical interest for separating signals. They permit, for example, separation of signals having overlapping frequency spectra and extracting them from additive noise. For this purpose linear networks with varying parameters can be used. Such networks are the special nontraditional sort of filters which are called signal-structure parametric filters. A special time function which contains information of the structural properties of the input signals controls the parameters of such filters.

A recent paper [40] by A. M. Zayezdnyi and V. A. Zaytsev, the method of synthesis of signal structural filters based on the concept of generalized resonance is outlined. The authors considered a filter which is described by a linear second order differential equation with varying coefficients. The synthesis problem consists in determining those coefficients for a given input oscillation and required filter response. In one of their examples, the authors give the synthesis of a filter for separating a pair of signals with angle modulation and with overlapping spectra. The authors "confidently expect that further work on signal-structure parametric filters will lead to the design of communication and location systems having improved characteristics especially in the light of recent technological advances in microelectronics."

In this author's opinion, once can expect to see in the near future further developments and new results in such filter areas as distributed, lumped-distributed, digital multiport and structure signal parametric filters. The computational difficulties which presently inhibit some important practical results will be overcome by the wide use of computers. As the development of radio-electronic systems and technology advances, new problems will arise that will lead to new results and research even in traditional filter problems which now seem to be solved.

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APPENDIX g)

1. Development of Filter Theory (S. Darlington)

HYSICS OF EVICES	LINES LOADING		MATHEMATICS COMPUTATIONS
OMPONENTS	LINEAR CIRCUIT THEORY	FILTERS	DIGITAL COMPUTERS
C			
		ITERATIVE	
CUUM TUBE			
			MECHANICAL
		Z_I SECTIONS	
	REALIZATION		
		GENERAL Z_I	
	OPTIMIZATION		
	INS. LOSS TH.	INS. LOSS	
	FEEDBACK		
T. OP. AMP.			
			ELECTROMECH.
	MORE GEN. CCTS	ACTIVE ANALOG	
NSISTOR			
			VACUUM TUBE
	STATE SPACE		
S. OP. AMP.			
			SOFTWARE
	COMP. AID. DES.	COM. AID. DES.	
DEVICES			
			TRANSISTOR
	DIGITAL CCTS	DIGITAL	
EGRATED IC & LIN.)			
		INTEGRATED	INTEGRATED
I.			
		L. S. I.	L. S. I.

APPENDIX g)

2. Filter Catagories and Interrelations of Papers (S. Darlington)

nalysis	III A 3^{1}, IV B 2
ealization	II 2^{1}, II 5^{1}, IV A 4
pproximation	III A3^{11}
Functions	II 2^{11}, II 7, IV 33
Optimization	IV A 2^{1}, IV A 3^{1}
Computer Aided	II 6, IV A3^{1}, IV B 7, IV B 8
tive Filters	
RC	I 2, I 3, I 5, I 6, IV A 1, IV A 6, IV A 8, IV B 6^{1}
RC-Distributed	II 1, II 5^{11}, III A 6, IV A 3^{11}, IV A 5^{11}
N-Path	I 4, II 4, II 8
Transversal	IV B 9
Integrated	IV B 4
gital	III A 1
Functional Design	III A 2, III A 4, III A 5, III A 7^{1}, III A 8^{1}
Integrated	
L. S. I.	
stal & Ceramic Filters	III B 1, III B 2, IV B 6^{11}
ustic Filters	III B 7, V 3, V 4
ical Filters	V 1, V 2^{11}
rowave Filters	I 7, II 3, III B 3, III B 4, III B 5, III B 6, III B 8
al Processing	I 8^{1}, III A 7^{11}, III A 8^{11}, IV B 1, V 2^{1}
cellaneous	I 8^{1}, IV A 2^{11}, IV A 7, IV B 5