AN ADMIRABLE MICROWAVE ENGINEER

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In 1944 while taking a course on electromagnetics taught by Professor Ronold W. P. King at Harvard University I barely noticed a quiet, unassuming, serious student. Later, I learned that his name was Seymour B. Cohn, a part-time student who was employed at the Radio Research Laboratory (RRL) in Cambridge, MA under the directorship of Dr. Frederick E. Terman. In 1948 Seymour received the PhD degree from Harvard and his dissertation dealt with ridge waveguide. This topic was important to RRL because of its application to wideband countermeasures.

Dr. Cohn joined Sperry Gyroscope Company in Great Neck, New York, and was engaged in the research and development of microwave components. In the spring of 1949 he visited Harvard, and we renewed our acquaintance. I heard of his employment and interesting work at Sperry. The conversation turned to my possible employment and interview at Sperry.

In the fall of 1949 I joined Seymour's Microwave Research Section at Sperry and was assigned to a challenging problem on multiple channel high power rotary joints. While heading the section he also undertook his own research on microwave coupling apertures and shielded strip lines. It was impressive to witness his diligence, dedication, thoroughness, confidence and determination to produce and to excel. After each tangible technical progress, he generously shared with and contributed his knowledge to the microwave profession through papers in journals and presentations at conferences.

In retrospect it was his good fortune to have a) selected a lifelong activity in which he had tremendous enthusiasm, b) excelled in performance and output, and c) had individuals and institutions who valued his output.

In recognition of his unusually high productivity and valuable contribution to the microwave profession he received several awards and recognitions. In 1960 he was elected to the grade of Fellow by the IEEE Board of Directors at the age of 39, probably the youngest age for this recognition. He received the MTT/S Microwave Prize in 1964. In 1974 he was awarded the IEEE Lamme Medal by the IEEE Board of Directors with the citation: "For outstanding contributions to the theory and practice of microwave component design." In 1980 he was recipient of the MTT/S Microwave Career Award. One of the IEEE Centennial Medals was presented to him in 1984.

In the April 1959 issue of the MTT Transactions, Dr. Cohn wrote an editorial titled "Breaking Through the Mental Barrier." Excerpts from it are:

> "Any of us whose work requires thinking will realize that the brain was not really meant for scientific effort...-the mind tends to form easy paths of thought, with access to new ideas blocked by over-generalized beliefs and over-extended assumptions. - In effect, misused principles are barriers to creative thought. To break through these barriers we must completely understand the range of validity of each principle, and realize that outside this range any principle may be as unreliable and treacherous as prejudice and superstition..."

Dr. Cohn has unusual insight and is very perceptive. He has strived for thoroughness with technical integrity. He has earned exceptional merit and technical trust, and he has been recognized many times. I believe he truly can be called "an admirable microwave engineer."

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AN OVERVIEW OF SOME IMPORTANT CONTRIBUTIONS TO MICROWAVE ENGINEERING

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ABSTRACT

This paper endeavors to give a brief overview of the many contributions to microwave engineering of Dr. Seymour B. Cohn during the period that he was at Stanford Research Institute (1953 to 1960).

INTRODUCTION

This paper briefly highlights the contributions of Seymour B. Cohn during the period from 1953 to 1960 during which he was at Stanford Research Institute, first as Head of the Microwave Group, and for the latter three years as Manager of the Electromagnetic Techniques Laboratory. The writer had the privilege of working in this laboratory during the last two years that Dr. Cohn was at SRI.

When Dr. Cohn first came to SRI interest in stripline as a microwave circuit medium was beginning to grow, but little design information was available. Similarly, techniques for the design of microwave filters were still relatively crude and few in number. Dr. Cohn made major contributions to the advancement of these areas while he was at SRI. As will be seen from the following, his work was always oriented towards practical and useful goals. Though he is a very capable mathematician, his special forte is to seek out the dominant physical mechanisms involved in problems and to then obtain relatively simple approximate design theory, equations, and charts which are invaluable to design engineers.

A truly complete description of Dr. Cohn's contributions while at SRI is not feasible in the available space, but a brief overview follows.

A. DESIGN THEORY FOR TRANSMISSION LINES AND OBSTACLES

In reference (18) (see list at end of this set of papers) Dr. Cohn presented highly accurate approximate formulas and graphs for stripline with arbitrary strip thickness. These results are still widely used. In (21) these results were extended to include equations and graphs which gave the attenuation and Q of stripline with arbitrary dimensions. This work was carried still further in (24) to cover the case of parallel, coupled striplines. By a conformal mapping technique, Dr. Cohn obtained exact expressions for the odd- and even-mode impedance of coupled striplines having negligible thickness and prepared nomograms which are extremely useful to designers for obtaining line dimensions to yield desired odd- and even-mode impedances. This paper also included additional equations and graphs which permitted approximate design of coupled strips having finite thickness or utilizing conducting strips photoetched on the top and bottom of a thin dielectric sheet (i.e., suspended stripline). In this latter case, the presence of the dielectric affects the odd- and even-mode velocities and approximate equations were provided for computing these quantities.

In (38) techniques for thickness correction for the analysis of capacitive obstacles in waveguide and a variety of other situations were obtained. For example, in (37) Dr. Cohn obtained rigorous theory for the odd- and even-mode impedances of zero-thickness coupled-strip configurations analogous to those shown in Figs. 1(a),(b). With the aid of the results of (38) structures having strips with finite thickness, as shown, could be designed. These structures, of course, are of special interest for the design of directional couplers or coupled-line filters with very tight couplings.

B. NEW MICROWAVE FILTER DESIGN THEORY AND STRUCTURES

Reference (29), perhaps one of Dr. Cohn's most important papers, delineates a very powerful and general point of view for the design of direct-coupled bandpass in filters of either lumped-element or distributed forms. Though the range of potential application of the methods described is much greater, the filter structures treated in detail in the paper are shown in Fig. 2. The coupling elements between resonators are modelled using the concept of "impedance inverters" which act similarly to quarter-wavelength lines. A structure which consists only of series (or of shunt) resonators separated by such inverters performs as though it was a classical bandpass filter consisting of a ladder network of parallel-type resonators connected in shunt alternating with series-type resonators connected in series. Though Dr. Cohn handled the process more directly, in principle one could work out a classical ladder bandpass filter design with a Chebyshev or other desired response from a lowpass prototype and then convert the ladder design to a more practical structure which uses a cascade of direct-coupled resonators all of the same desired type (as for the examples in Fig. 2). Since the couplings (i.e., impedance inverters) were frequency sensitive, the responses of the filters in Fig. 2 are skewed as compared to that of a classical ladder-type bandpass filter. Dr. Cohn introduced mapping functions which accounted for this skewing. These mappings along with the other features of his method made it possible to obtain bandpass filter designs which were quite accurate for as much as 20 percent bandwidth whereas previous methods for such filters were accurate for bandwidths of only a percent or so.

Using the methods in (29) Dr. Cohn obtained equations for the design of filters of the type in Fig. 3 from lowpass prototypes (31). Because these filters do not require any ground connections and because the coupling gaps between the resonators are relatively large, this type of filter is extremely practical for photoetched stripline or microstrip bandpass filters of narrow to moderate bandwidths. It is safe to speculate that

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they are, by far, the most widely used type of bandpass filter for such applications, and they found their wide use as a result of reference (31).

Directional filters are an important class of filters which were researched by Dr. Cohn along with Frank Coale (27). Their paper describes a number of stripline directional filter types in addition to waveguide types. Figure 4(a) shows a single-resonator directional filter of the ring-resonator type, while Fig. 4(b) shows a two-resonator version. Other capacitive-gap-coupled versions are also shown, but the ring-resonator forms have been by far the most popular. For frequencies in the passband of these filters, power entering at port 1 at the lower left will emerge at port 4 at the upper left. Meanwhile, power at frequencies away from the passband of the filter will emerge at port 2 on the lower right. Since power entering port 1 will always end up at either port 2 or 4, the input impedance seen at port 1 is always reflectionless (to a very good approximation). This has made directional filters very attractive as channel dropping filters in multiplexers. A large number of such filters can be cascaded without adverse interaction effects between the filters.

In Fig. 5 is shown a two-resonator waveguide directional filter such is also treated in (27). In this case circularly polarized resonances are excited in the cavities which lead to the directional properties of the filter. For these filters in the passband the output power appears at the upper port on the right, but otherwise the performance is very similar to that of the filters in Fig. 4.

A very clever kind of filter invented by Dr. Cohn is the "waffle-iron", lowpass waveguide filter. Prior to the advent of the waffle-iron filter, lowpass waveguide filters consisted of corrugated waveguide structures having grooves running in the width direction of the top and bottom walls of the guide (7). These structures are normally designed to operate in the TE_{10} mode and work well as long as only that mode is present. However, at frequencies in their stop band higher-order modes can propagate in the waveguide. If such modes are present it is found that spurious passbands will result. By insight which is very simple once it is understood (but which was previously unknown), Dr. Cohn saw that spurious passbands resulting when higher-order modes are present could be prevented if the structure is corrugated in both the length and width direction of the guide making a pattern much like a waffle iron as shown in Fig. 6. (The complete filter also utilizes impedance-matching transformers at the ends, which are not shown in this figure.) Dr. Cohn's original work on waffle-iron filters was only published in Signal Corps reports. However, in Sec. 7.05 of the reference below* a description of the design of filters of this type is presented based, in part, on later work at SRI done by Eugene Sharpe, Leo Young, and B. M. Schiffman after Dr. Cohn had left. Some of Dr. Cohn's original waffle-iron filter designs were (and still are) manufactured by Hewlett Packard, and possibly others. A prime application has been for the removal of the second- and third-harmonic frequency components from signal sources having waveguide outputs.

While at SRI Dr. Cohn published several other significant filter-related papers. One of them is (32) which deals with predicting the power-handling ability of waveguide bandpass filters and design options which can increase the power rating of such filters. Another is (34) which deals with predicting the passband loss due to dissipation in bandpass filters. Yet another is (36) which analyzes the phase and time-delay characteristics of maximally flat and Chebyshev narrow-band bandpass filters.

*G. L. Matthaei, Leo Young, and E.M.T. Jones, <u>Microwave Filters, Impedance-Matching Networks, and Coupling Structures</u>, Artech House, 1980.

C. SOME OTHER MICROWAVE-CIRCUIT CONTRIBUTIONS

In (23) Dr. Cohn published a very practical method for the design of wideband step transformers. Previously, W.W. Hansen had developed an approximate design method for step transformers which ignored second- and higher-order reflections from the discontinuities and defined the desired transfer function in terms of binomial coefficients in a manner similar to those used for "binomial" antenna arrays. Dr. Cohn used similar techniques based on Chebyshev array theory to obtain simple approximate means for designing step transformers having a Chebyshev frequency response. Until Leo Young's tables of exact Chebyshev transformer designs were published, (23) was the standard way for designing wideband step transformers. It is still attractive for some cases not treated by tables.

Paper (19) discusses a novel way of measuring impedance in a rectangular waveguide by use of a perpendicular cylindrical guide mounted on top of the rectangular guide with several coupling apertures at the guide interface situated so as to create circular polarization in the circular guide. This structure has some attractive properties for measuring impedance and a useful bandwidth of about 20 percent. In (35), coauthored by Dr. Cohn, a novel, wideband, nonreciprocal structure is discussed, while in the invited editorial (33) Dr. Cohn points out the need to be open-minded to potential breakthroughs in the limits of microwave technology as presently perceived and cites examples.

D. MICROWAVE LENS ANTENNAS

Dr. Cohn also worked on some antenna-related problems while at SRI. In (22), (25), and (26) he and his coauthors (E.M.T. Jones, and/or T. Morita) describe techniques for producing anti-reflection coatings on microwave dielectric lenses by use of "reactive walls" embedded within the surface of the lens (22), (25) or simulated quarter-wave coatings (25), (26). For example, the capacitive-reactive walls utilized in some of the experiments described in (25) consisted of an array of round, conducting disks about 3/8 of a wavelength beneath the surface of the faces of the lens. In the case of the designs using quarter-wave surface-matching layers it was not practical to actually coat the lens with an appropriate dielectric so, instead, the desired effective dielectric constant was achieved by use of a layer of corrugations, arrays of holes, or waffle-iron patterns on the surface of the lens. In one example a lens antenna design with sidelobes peaks at about the -19 dB level improved so the sidelobe peaks dropped to around -33 dB when a capacitive-reactance wall was used within the lens surface to minimize reflections (25).

E. CONCLUSION

As can be seen from the foregoing, Dr. Cohn's years at SRI were extremely productive and valuable to the microwave community.

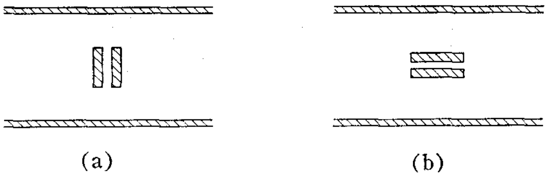

Fig. 1 Some coupled-strip configurations treated in (37) with the aid of (38).

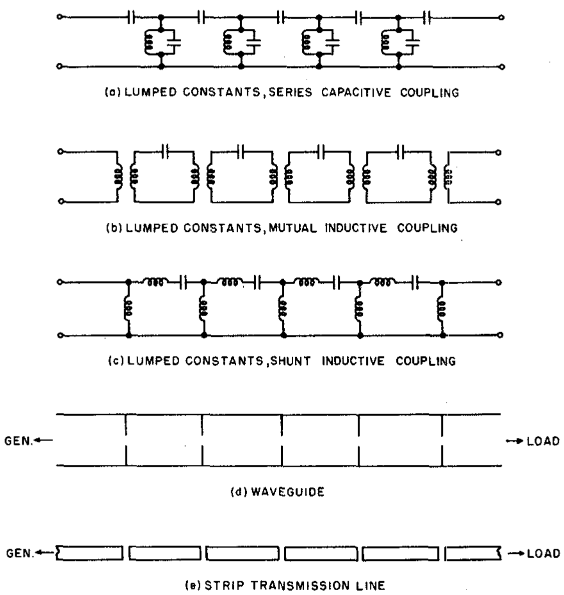

Fig. 2 Improved design theory for these example filter-structures is given in (29).

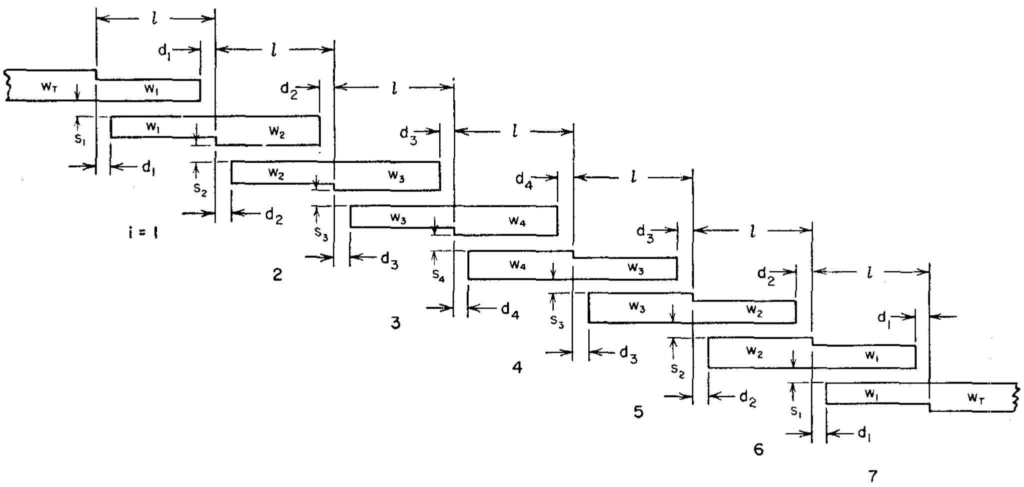

Fig. 3 Design theory for this important kind of filter was first given in (31).

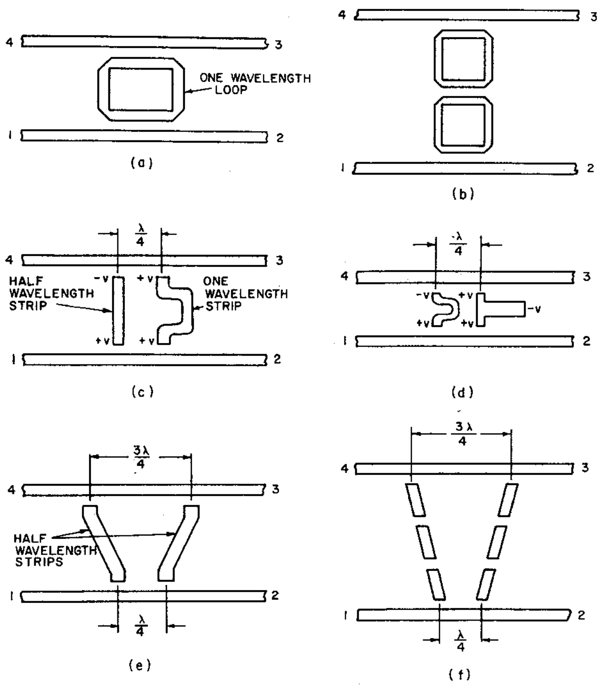

Fig. 4 Printed-circuit directional filters treated in (27).

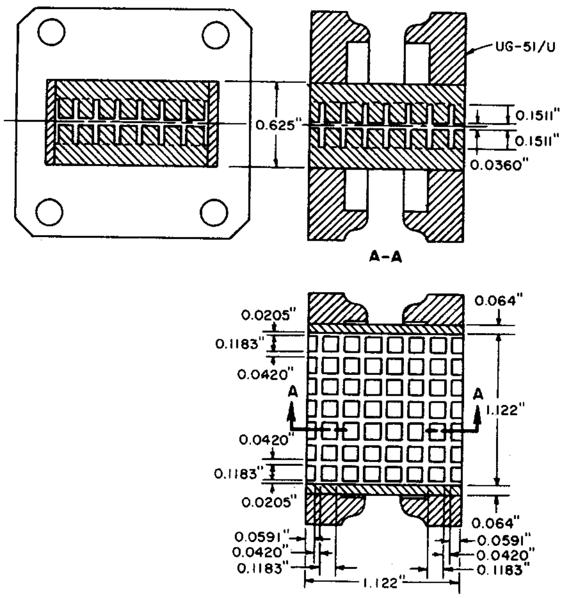

Fig. 6 A "waffle-iron" low-pass filter invented by Dr. Cohn. (Figure courtesy of Artech House.)*

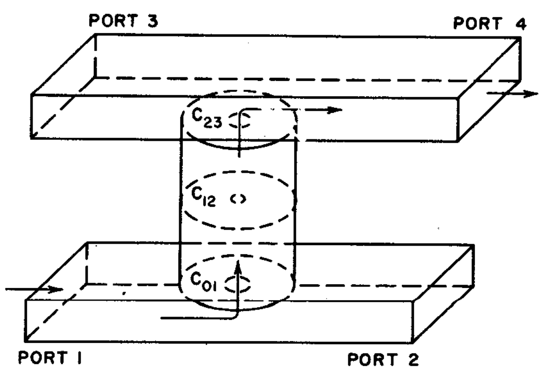

Fig. 5 A two-resonator waveguide directional filter also treated in (27). (Figure courtesy of Artech House.)*