Coupled Microstriplines as Filter

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This article is based on a lecture given at the Munich VHF-UHF Convention in 1980. The task of this article is to give UHF/SHF amateurs an insight into the exact calculation and construction of microstripline filters. It will also introduce tables that allow a simple and exact determination of the filter dimensions. The tables also offer valuable assistance for further applications in microstripline technology. The complete calculation process with examples would be too extensive to be described here, however, it is possible to obtain a reprint of the lecture, and to obtain completed 13 cm filters from the author. Further details regarding this are given at the end of the article.

FUNDAMENTAL CONSIDERATIONS

Many of our readers with experience in directional coupler technology will know that coupled lines are not defined with the system-dependent impedance Z_0, but with the Even-Mode impedance Z_{oE}, and the Odd-Mode impedance Z_{oO}. Examples for balanced configuration in a homogene medium (air) can be found in many standard works such as in (1).

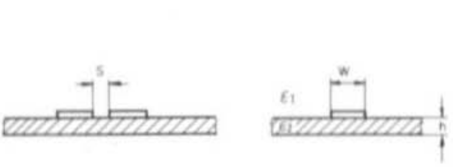

Fig. 1: Striplines in inhomogene medium (microstriplines). Left: Single line; Right: Coupled lines with $\varepsilon_{r\,eff} = K_{EFF} = \sqrt{K_{EFFE} \times K_{EFFO}}$

If, however, the coupled lines **(Figure 1)** are to be found in a homogene medium (dielectric $\varepsilon_r = 2 - 10$), the calculation will become very complicated and approximation formulas will only show a limited accuracy, which means that these are unsuitable for the construction of filters. The same is valid for an individual stripline in an inhomogene medium. The exact calculation of the mechanical dimensions w/h and s/h with respect to Z_0 or Z_{oE} and Z_{oO}, with an error of < 1 %, would be virtually impossible for most radio amateurs. An example of a calculation of w/h using too simple a formula is to be found in (7) where the error is in the order of approximately 15 %.

The »exact« calculation of microstriplines was firstly possible in 1969 with the aid of the »BRYANT-WEISS« method (3). The mean error only amounts to 0.7 % ! In order to take the problem of the inhomogene medium into consideration, the »Dielectric Green's Function« is used. This allows the discontinuities of the fields at the edges of the medium to be considered. The calculations according to (3) can only be made using large computers such as CYBER 176, and these have been carried out. The resulting tables allow anyone working with microstriplines to read off the mechanical dimensions at any given Z.

The given accuracy is especially necessary during the calculation of filters. An extract from this list of tables for coupled lines on a RT/duroid 6010 dielectric with $\varepsilon_r = 10.25$ is given in **Figure 2**.

If this list of tables is available, the dimensions can be read off directly for such applications as matching circuits, lines, inductances, capacitances, open and short-circuited stubs, coupled lines for directional couplers, power dividers, matching networks for antenna arrays, filters with coupled lines, and much

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 MICROSTRIP, SHIELDED MICROSTRIP OR QUIT (MS/SH/QU) ? MS
 ENTER SINGLE OR COUPLED LINES (S/C)? C
 NO. SUBSTRIPS PER STRIP (25 MAXIMUM) ? 10
 ENTER RELATIVE DIELECTRIC CONSTANT ? 10.25
 UNITS: ENGLISH, METRIC OR RATIOS (E/M/R) ? R
 FOR W/H: ENTER START, STOP, AND STEPSIZE ? 0.5 2 0.5
 ENTER S/H RATIO? 1

    COUPLED STRIPS      S/H =  1.000           K = 10.25

    W/H         Z0E     Z0O          VE      VO         KEFFE   KEFFO
                   OHMS              E+08 M/SEC
    .500       75.332  56.401       1.130   1.235       7.045   5.894
   1.000       55.211  42.545       1.100   1.213       7.431   6.111
   1.500       44.115  34.951       1.079   1.192       7.718   6.329
   2.000       36.874  29.882       1.064   1.173       7.945   6.533


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Fig. 2: Printout of a calculation table

more. It is possible, for instance, for a 13 cm converter to be calculated which comprises two preamplifier stages, a travelling-wave directional filter, or alternately a filter with parallel-coupled lines for 20 dB suppression of the image frequency, a printed subharmonic mixer with $f_{osc.}$ = 1080 MHz, and an IF-preamplifier at 144 MHz, all accommodated on a board of approximately 70 mm x 50 mm. This would represent the end of the considerable mechanical requirements of the chamber technology.

APPLICATIONAL EXAMPLE

The »theory« is now to be shown with the aid of a practical example.

Firstly it is necessary to briefly discuss the calculation fundamentals for filters using coupled lines, after which the mechanical construction and measured values are to be discussed.

This filter is constructed in the manner shown in **Figure 3**:

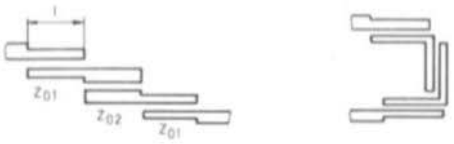

Fig. 3: Filter with coupled lines of stage 2 showing two possible arrangements;
$L = \lambda/4 \times 1/\sqrt{\varepsilon_{r\,eff}}$

The following is required for calculation:

- Tables for determining the Tschebyscheff-lowpass coefficients and the degree of filtering n, which can be found in any handbook covering filter fundamentals, such as (1), (2), (5); the complete filter calculation is given in (1) and (8).
- The mentioned tables for determining the values of w and s of the coupled microstriplines.

The calculation process for coupled lines was carried out according to (1).

The values Z_{oE} and Z_{oo} for the individual coupled line sections are obtained with the aid of simple, short calculations. The mechanical dimensions are determined with the aid of the microstripline tables, after which the filter can be constructed.

The filter has the following specifications:

Characteristics	calculated	measured
Bandwidth	200 MHz	160 MHz
Insertion loss	< 1 dB	0.8 dB
Center frequency	2300 MHz	2280 MHz
Stopband loss at 2000 MHz (f_{image})	20 dB	20 dB

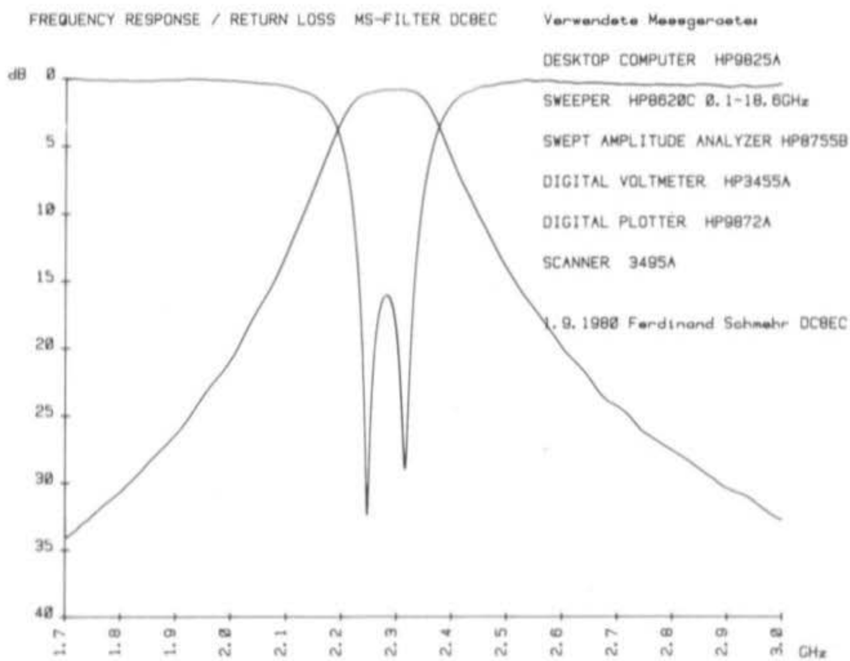

Fig. 4: Frequency response and return loss of the filter shown in Fig. 3

Figure 4 shows the measured frequency response and return loss curves of this filter.

The measurements show that the required filter specifications can be obtained without problems and alignment. The tabular values were calculated using the large computer CYBER 176. The program used was the HF-program COMPACT/RFOPT.

The calculations were carried out for:

- Epoxy material with $\varepsilon_r = 4.8$
- PTFE glas fibre material with $\varepsilon_r = 2.55$
- RT/duroid 5870 with $\varepsilon_r = 2.35$
- RT/duroid 6006 with $\varepsilon_r = 6$
- RT/duroid 6010 with $\varepsilon_r = 10.25$

The following tables are available:

1. According to »BRYANT-WEISS«:

- Single-strip transmission lines for w/h from 0.4 to 15 with 0.2 steps; available for DM 10.—
- Coupled-microstrip transmission lines: 7 tables for w/h from 0.5 to 10 with steps of 0.5, and s/h from 0.3 to 2.1 with steps of 0.3; available for DM 40.—.

2. As under 1., however, calculated with the aid of an approximation (mean error approx. 3 %):

- Single-strip transmission lines (DM 7.—)
- Coupled-microstrip transmission lines (DM 22.—).

Other ranges and steps of w/h and s/h of microstrip and triplate lines are available at short notice from the author.

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