II-5 A COMPUTER DESIGNED, 720 TO 1 MICROWAVE COMPRESSION FILTER

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An outgrowth of development work on rapid-scan receivers has been a broadband microwave linear-delay compression filter.* This filter utilizes a folded-tape transmission line (FTML)** between ground planes to achieve a time-bandwidth product (compression factor) of up to 1000 with bandwidths of 1 GHz or more. A filter has been constructed using the FTML technique for use in a Navy high-resolution radar techniques investigation; measurements on this filter are presented as experimental verification of the design technique.

The basic element of the FTML is a strip transmission line in which the conducting strip, instead of being oriented with the flat side parallel to the ground planes in the conventional manner, is placed perpendicular to the ground planes. This strip is bent back and forth upon itself as shown in Fig. 1 to form a meander line in which electromagnetic coupling takes place between adjacent turns. The spaces between adjacent turns of tape and between the tape and the ground planes are filled with dielectric material. The dimensions S, W, B, D, and L shown in Fig. 1 determine the electrical properties of the meander line. Each FTML turn has a delay peak at a frequency f_o (and at odd multiples of f_o) whose magnitude is determined by the amount of electrical coupling between the turns; the lowest resonant frequency of a FTML turn is the frequency at which L is a quarter wavelength in the dielectric.

The phase and time-delay of a single FTML turn is shown in Fig. 2 for several values of a coupling coefficient γ. Note that for $\gamma = \infty$ (zero coupling) the FTML turn exhibits a linear phase characteristic and has a constant delay of $0.25/f_o$ seconds as one might expect. The delay of a FTML with infinite coupling would be zero everywhere except at $f/f_o = 1, 3, 5$, etc. where it would be infinite. The time-bandwidth product TW of a single FTML turn (the area under the $f_o\tau$ vs f/f_o curve) is independent of γ for $0 \leq f/f_o \leq 2$ and is equal to 1/2. Thus a compression filter with TW = 1000 would require a minimum of 1000 FTML turns. Filters constructed with the FTML technique to date indicate that this value can be approached within approximately a factor of 2 with a realistic figure being 2350 turns for a filter with TW = 1000.

A short computer program (less than 5 minutes on an IBM 7090) has been written to synthesize linear delay vs frequency characteristics using FTML sections. The computer will calculate the number of turns necessary at each of a number of different f_o's to realize a desired delay function. Figure 3 illustrates how three FTML sections with $f_o = f_1$, f_2, and f_3 could be used to coarsely approximate a linear delay characteristic as indicated by the total delay $\tau_1 + \tau_2 + \tau_3$ of the three sections.

* This work was performed under Army Contract DA 28(043)-AMC-01764(E).

** Originally described by V.E. Dunny in "Realization of Microwave Pulse Compression Filters by Means of Folded-Tape Meander Lines," Rept. SEL-62-113 (TR No. 557-3), Stanford Electronics Laboratories, Stanford, Calif.

The FTML technique has been used to construct a linear-delay compression filter with a 1.2 μs differential delay over a 600 MHz frequency range centered at 1350 MHz. This filter, with a TW of 720, was constructed in four identical sections, one of which is shown in Fig. 4. For purposes of clarity, the upper dielectric sheet has been removed from the filter in the photograph. Spurious modes are prevented from propagating between the ground planes by a microwave absorber material packed into the cavities. The filter was constructed in four separate sections in order to conveniently allow the use of only a portion of the filter in the radar system and to simplify the problem of amplitude weighting by limiting the insertion loss through any one filter. The insertion loss of this filter is approximately proportional to the delay, the constant of proportionality being about 0.1 db/ns.

The measured delay and insertion loss are plotted point-by-point in Fig. 5. The size of the plotted delay points represents the measurement uncertainty, about $\pm$ 1 ns. The measurement was made using a phase detector to measure the frequencies at which the phase shift through the filter was equal to multiple of 2π; the delay was then taken to be $2\pi/\Delta\omega$.

Linear-phase weighting networks are under development to provide an overall transfer function shape with sufficient band-edge weighting to provide 30 db or better sidelobe levels. The basic delay characteristics of the filter are sufficiently accurate to make these low sidelobe levels possible.

The folded tape meander line technique, combined with the computerized synthesis procedure, makes possible a rugged, compact compression filter with accurate delay characteristics. The input and output impedance is predominately resistive at approximately 30 ohms for most practical configurations. A report providing detailed design information for FTML compression filters is in preparation and will be available this summer.

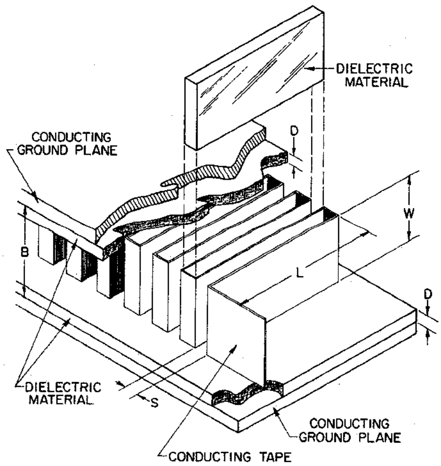

FIG. 1. Folded Tape Meander Line Configuration

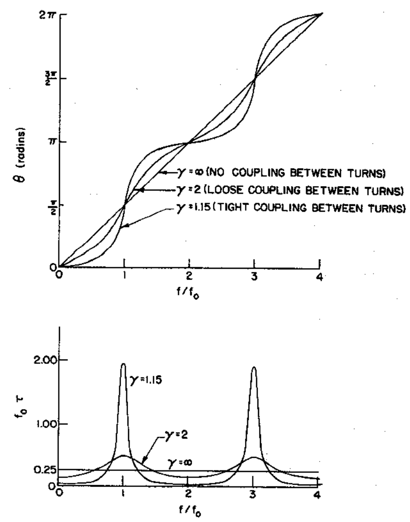

FIG. 2. FTML Phase and Time Delay vs f/f_0

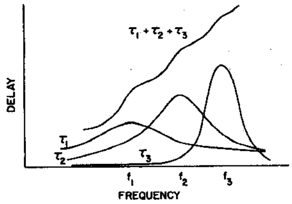

FIG. 3. Linear Delay Synthesis with Three FTML Sections

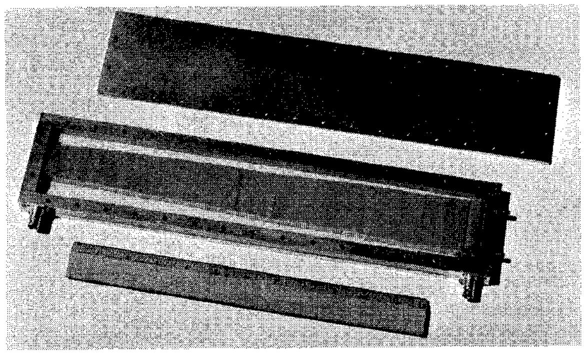

FIG. 4. One of Four Sections of 720:1 Compression Filter (Scale is in inches)

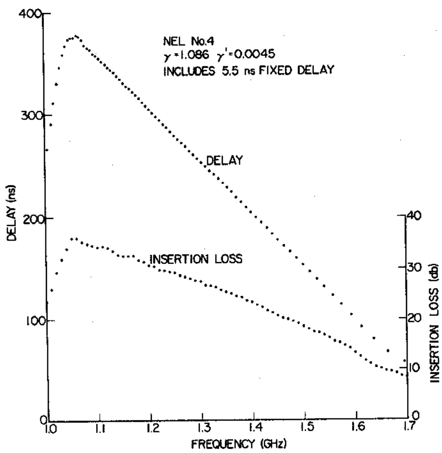

FIG. 5. Delay and Insertion Loss vs Frequency for Compression Filter Section of Fig. 4.