EXTENDED-JUNCTION COMBLINE MULTIPLEXERS

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ABSTRACT

A broad-band combline multiplexer can be built with a single common junction. When there are several channels or some of them are relatively narrow, the use of an "extended junction" may prove advantageous.

Introduction

Combline bandpass filters, when properly designed, can be connected together at a common junction to form a frequency multiplexer. Combline multiplexers can be built to satisfy a wide range of requirements. A contiguous-channel combline triplexer of moderate bandwidth was described in 1967.[1] More recently a minimum-susceptance combline filter with a series-resonant input coupling has been introduced.[2,3] This allows a common-junction multiplexer to operate over multi-octave bandwidths.

The common junction is not without its practical difficulties, however. The connecting lines should be commensurate with the resonators, and at the higher frequencies this length can be quite short. It is also important that the first shunt resonators of the different channel filters not be allowed to couple directly among themselves, and that they be kept large enough to be easily tunable and to have low loss. These requirements taken together make the junction area more crowded and difficult for increasing frequency and number of channels. When frequencies above 10 GHz are involved, it can be difficult to lay out the junction of even a triplexer, let alone a quadruplexer or quintuplexer.

There is another difficulty peculiar to the series-resonant input coupling. As in all exact TEM filters the impedances are best behaved in the vicinity of 100% bandwidth. As the bandwidth becomes narrower in a bandpass filter, the impedances of the shunt branches become lower while those of the series branches become higher. Consequently, the impedance of the series-resonant circuit to the junction increases to the point of difficulty for bandwidths below 40%.

A solution to both the overcrowding and the narrow bandwidth problems is to put some of the channels into subgroups which are connected together at subsidiary multiplexing junctions, which are then, in turn, connected to the main junction through one or more coupling elements. This technique, the "extended junction," is the subject of this paper. In the past it has been used occasionally in low frequency and narrow bandwidth applications. It is actually applicable to a wide range of frequencies and bandwidths. Its use will be demonstrated by example, and a design approach will be presented.

Example: 8-18 GHz Quintuplexer

A requirement existed for an 8 to 18 GHz quintuplexer with crossovers at 10, 12, 14 and 16 GHz. The device had to be manufactured in large quantities, making reproducibility very important.

When five channels are connected in parallel at a single junction, there is a problem. A direct path for coupling from the common node to the first element in each channel must exist, yet coupling from one channel to another must not. At these high frequencies, it is not practical to meet these criteria and keep the coupling lines short enough for good performance.

One solution is break up the coupling through the use of sub-junctions, shown schematically in Figure 1. These sub-

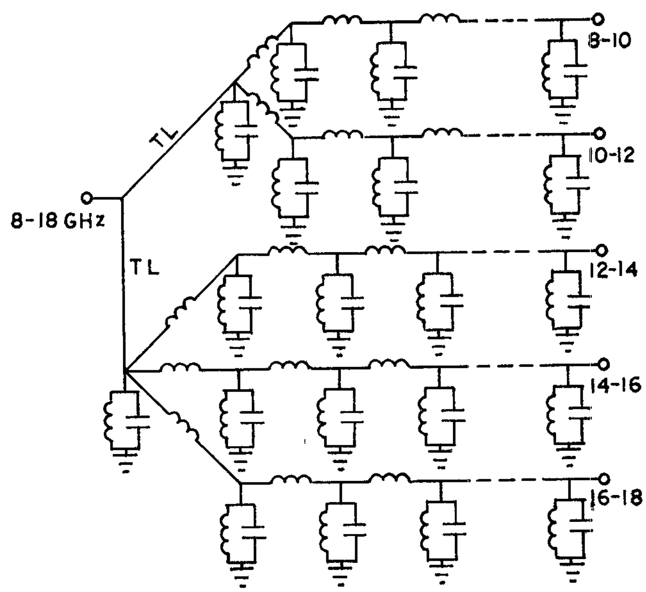

FIG. 1 - SCHEMATIC FOR 8-18 GHz QUINTUPLEXER

junctions provide a means of separating the channel filters to allow adequate space for channel definition. It is important to keep the sub-junction areas large enough for tuning adjustments.

The individual filters are singly-terminated and the sub-junction stubs are susceptance modifiers. Final susceptance annulling is done via the transmission lines to the main junction and capacitance from the junction to ground.

Each sub-group of filters is designed with commensurate resonators, with the physical lengths chosen to provide reasonable electrical lengths in all channels. The main distribution network, including the sub-junction stubs, is machined from a single piece, providing for repeatability in the critical junction area. Only six solder joints are required in the assembly of the entire quintuplexer, thus enhancing its reliability. A photograph of the interior of the finished device is shown in Figure 2.

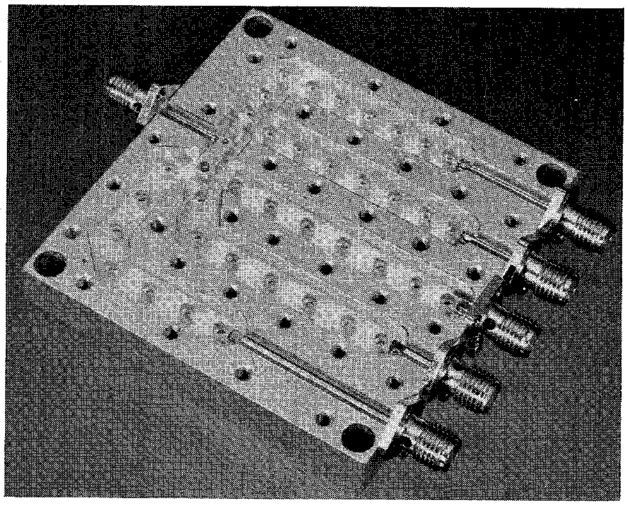

FIG. 2 - INTERIOR OF 8-18 GHz QUINTUPLEXER

Electrical performance of the unit was good. Crossover insertion losses were less than 5.5 dB. Crossover temperature drift was less than ± 10 MHz from -54 to +85 degrees Celsius. Impedance match at all ports could be tuned to greater than 12 dB return loss. Channel response curves are shown in Figure 3.

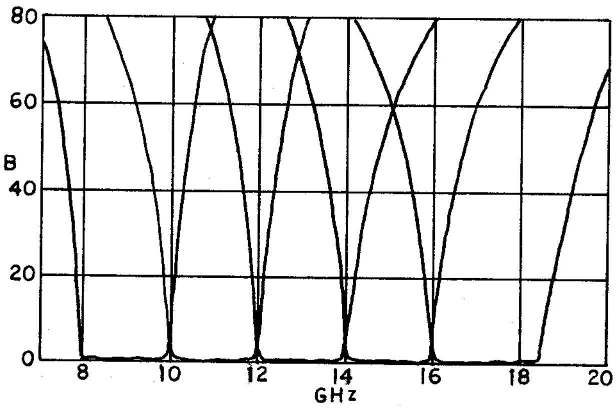

FIG. 3 - RESPONSE OF 8-18 GHz QUINTUPLEXER

Design Approach

The extended junction is conceptually simple. In the narrow-bandwidth case the design is straightforward as well, and can often be worked out with a Smith chart alone. In the broad-band case, however, particularly when the channels are contiguous, a systematic design approach is required.

In order for a multiplexer to be matabed, the input admittance at the common port must be real and constant over all the channels. For channel filters connecting directly to the main junction, a singly-terminated minimum-susceptance design is appropriate. This type of design can provide an input admittance with a real part which approximates a constant value over the channel width. The non-zero imaginary part can then be cancelled out by the imaginary parts of the other channel filters and an annulling network, using established procedures.

In the case of the extended junction, however, two or more channel filters are first connected together at a sub-junction, which is then connected to the main junction through either transmission lines or reactive coupling elements. In order for the real part of the admittance over these channels to be constant at the main junction, it must be other than constant at the sub-junction, because of the series elements between the two. The design criterion for the channel filters, then, is to synthesize them such that their input admittances at the sub-junction combine to form a characteristic which will cause the admittance at the main junction to have a constant real part. The imaginary part can then be handled in the same manner as for a single channel filter. The technique will be demonstrated by an example.

Example: 2-18 GHz Quadruplexer

A multiplexer was required with four contiguous channels between 2 and 18 GHz. The crossovers were at 6, 10 and 14 GHz. A topology including an extended junction was chosen, shown in Figure 4. The 2-6 GHz channel, because of its low

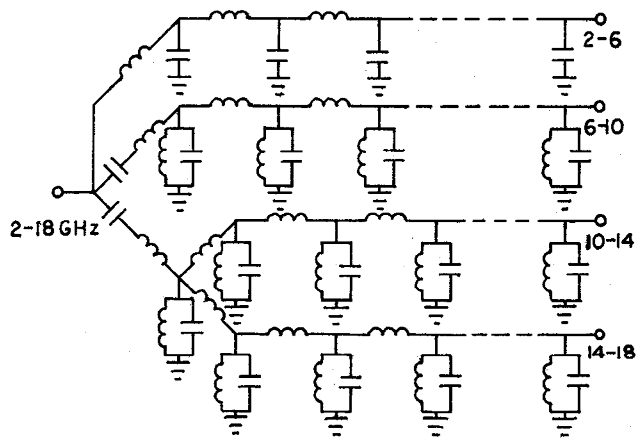

FIG. 4 - SCHEMATIC FOR 2-18 GHz QUADRUPLEXER

frequency and wide bandwidth, was realized with a low pass filter to the input junction, followed by a high pass filter (not shown). The 6-10 GHz channel was realized by a minimum-susceptance combline filter with a series-resonant input branch. The 10-14 GHz and 14-18 GHz channels were too narrow to couple conveniently to the input junction with individual series-resonant branches, and space was limited in the junction region. It was decided, therefore, to connect them together at a sub-junction which was then connected to the input junction through a single series-resonant branch.

The first step in the design of the two high channels was to synthesize a single 10-18 GHz singly-terminated minimum-susceptance combline filter with selectivity comparable to the outside skirts required for the two channel filters. The series-resonant input branch of this filter was taken to be the input branch to the sub-junction, and the admittance at the first node beyond this branch was calculated, shown in Figure 5.

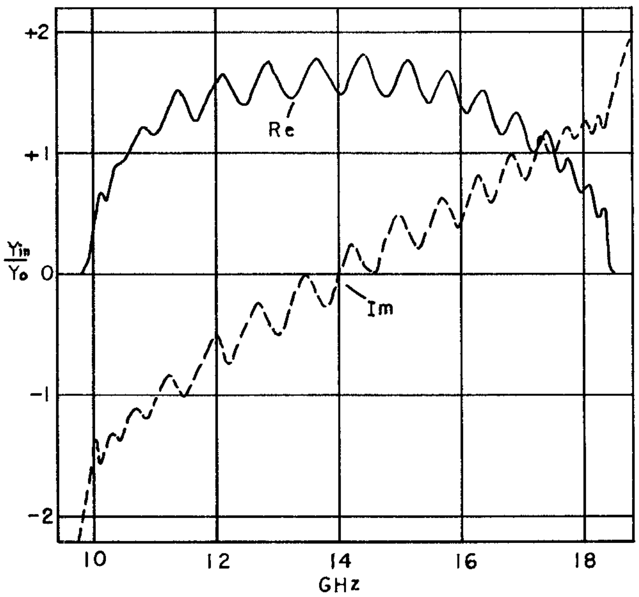

FIG. 5 - ADMITTANCE OF 10-18 GHz FILTER AT NODE BEYOND SERIES-RESONANT BRANCH

This characteristic then became the goal for the combined admittance of the two channel filters plus any adjusting susceptance at the sub-junction. The 10-14 GHz and 14-18 GHz filters were then designed as singly-terminated combline filters with series-inductance input branches. These gave an input admittance with a constant real part at the sub-junction, not what was needed. By suitable adjustment of the first few elements of each filter, however, a reasonable approximation to the desired real part was achieved. Then the imaginary part was further adjusted for proper slope and zero-crossing by adding shunt susceptance at the sub-junction. Finally the series-resonant branch was added, and the input admittance to this combination was calculated and is shown in Figure 6. This is a reasonable approximation to the admittance of the exactly designed 10-18 GHz filter, and it represents generally acceptable filter performance. Further manipulation of the input elements of the two filters could improve the admittance approximation and the overall performance.

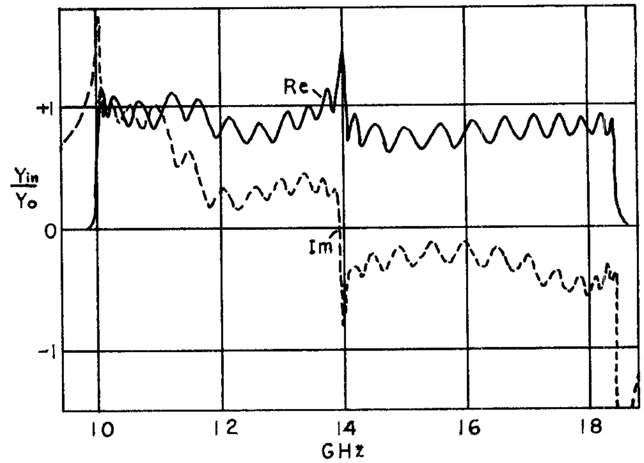

FIG. 6 - INPUT ADMITTANCE TO 10-18 GHz SUB-GROUP

Conclusion

The extended junction is a useful multiplexing technique. It offers no electrical advantage over the common junction, and it is more difficult to design, but its advantages in physical realizability are considerable and make the extra effort well worth while. In fact, of the broad-band combline multiplexers which have been built, more utilize extended junctions than common junctions. An approximate design method has been worked out which can be refined to an exact design.

References

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