A NEW TECHNIQUE FOR DESIGNING HIGHLY STABLE HIGH EFFICIENCY VARACTOR MULTIPLIER CHAINS

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Description of Method

In designing varactor multiplier chains, it is normally necessary to include isolators between the multipliers in order to eliminate spurious signals which are due to parametric oscillations. These oscillations can occur when two adjacent multipliers are not perfectly matched. In this paper, we shall present a method for the design of multiplier chains which are highly stable, eliminating the need for isolators.

A parametric oscillation occurs when at two frequencies, $\omega 1$ and $\omega 2$, whose sum is equal to the pump frequency (either the input or output frequency), the impedances seen by the varactor satisfy certain conditions. (For the abrupt junction non-overdriven varactor doubler, the conditions for parametric oscillations to occur are given in Reference 1.) However, for all varactor multipliers, whether the varactor is overdriven or not, if the impedances seen by the varactors at $\omega 1$ and $\omega 2$ have a sufficiently large real part, parametric oscillations will not occur.

The basis of the scheme employed in this technique is to terminate the varactor in a dummy load at all frequencies at which the conditions for parametric oscillation to occur can exist. This dummy load will provide the large real part necessary to prevent parametric oscillations.

One method for accomplishing this is to use a triplexer with four parts such as the one shown in Figure 1. The varactor is coupled to port 1 and the triplexer has the following properties: port 1 couples only frequencies in a passband around ω_o to port 2, port 1 couples only frequencies in a passband around $n\,\omega_o$ to port 3; all frequencies below $n\,\omega_o$ except for ω_o, appear only at port 4 which is terminated in a dummy load; all frequencies above $n\,\omega_o$ are reflected at port 1 and do not appear at any of the other ports. This triplexer can be designed to look like 50 ohms for frequencies below $n\,\omega_o$ at any port when the other ports are terminated in 50 ohms.

The degree of isolation between ports for frequencies outside of the designed passbands is a function of the number of sections used in the diplexers which make up the triplexer. It has been found that for compact broadband TEM microwave filters,

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a representative value for the insertion loss is approximately 0.1 db per section. If a diplexer is well matched, a minimum isolation of approximately 17 db will add 0.1 db to the corresponding passband loss. The decrease in passband loss achieved by increasing the isolation beyond 17 db by use of additional filter sections is normally matched or exceeded by the increased passband dissipation caused by the additional filter elements. For an n times multiplier, it is desirable that harmonics other than the n^{th} be at least 20 db below the n^{th} harmonic at the output terminal, but some of this is accomplished by the varactor itself which develops less power at harmonics higher than the n^{th}, and by the matching network which does not resonate the varactor at frequencies other than the fundamental and the n^{th} harmonic.

The triplexer is used as an n times multiplier by connecting an input source to port 2, load to port 3, and a dummy load to port 4. The matching network for the varactor is connected between the varactor and port 1, and matches the varactor to 50 ohms at ω_o and $n\,\omega_o$. The input signal is then coupled only to the varactor port, the output signal is coupled only from the varactor to the output load, and all frequencies below the output frequency, where parametric oscillations could occur, are coupled to the dummy load at port 4, preventing the oscillations. Since no oscillations occur, no power is dissipated in port 4, and there is no consequent loss in efficiency. Since all signals above $n\,\omega_o$ are reflected at port 1, there is no power dissipated at harmonics higher than $n\,\omega_o$. Harmonics below $n\,\omega_o$ are allowed to flow in idler circuits which are incorporated in the matching network. These idlers are designed to prevent power from reaching port 1 and hence the dummy load at port 4.

The multiplier can be made to have a broad bandwidth by designing the passbands of the triplexer and the matching network to have the desired bandwidths.

Using the method described above there is no possibility for parametric oscillations to occur regardless of the output and input match. A possible physical configuration for this multiplier is shown in Figure 2. It consists of a low pass filter with a cut-off just above $n\,\omega_o$, followed by a cascade of two complementary, 50 ohm band-pass band-stop diplexers. The first diplexer has its passband at $n\,\omega_o$. All other frequencies pass through the band-stop filter to the second diplexer which has its passband at ω_o. All other frequencies are terminated in the dummy load. Because the diplexers are complementary, the impedance seen at all ports is 50 ohms when the other ports are terminated in 50 ohms. Design procedures for complementary band-pass band-stop diplexers are given in References 2 and 3.

Experimental Results

To verify the practicality of the technique, an experimental model was constructed. The model was built of lumped components at UHF. It consisted of two doublers which were cascaded. The input frequency to the first doubler was 200 GHz and the output frequency of the second doubler was 800 GHz.

Both doublers were built in the configuration in Figure 3. This alternate configuration was used for convenience in the placement of circuit elements. In lumped components, there is no significant difference between the two configurations. In transmission line construction, care must be taken because of repeating passbands which occur due to commensurate line lengths.

Each of the two band-pass band-stop filter pairs of the doublers were designed as complementary filters with 50 percent 3 db bandwidth and an impedance level of 50 ohms. A three element maximally flat low-pass filter, shown in Figure 4, was used as the prototype for the design of all the filters, using the standard low-pass to band-pass and low-pass to band-stop transformations.

Due to the non-linear nature of lumped components over an octave range at UHF frequencies, it was necessary to change certain circuit elements from their design values in order to obtain the best overall response for the diplexers. The inductances used were air coils wound of number 18 wire, and the capacitances were Johansson variable capacitors.

The varactors used in the circuit were a VAB 803 and a VAB 804. An effort was made to use varactors that were at a 50 ohm impedance level, in order that the problem of matching the varactor to the diplexer be reduced to that of only resonating the varactor. While the actual varactors used in the circuits, had real parts of approximately 43 and 54 ohms, they were considered to have real parts of 50 ohms. This was done because matching their actual values to 50 ohms would require the use of excessively large coils or more complicated circuit branches, accounting for more losses than the slight mismatch creates. In addition, the placement of this branch of the matching network in shunt at the common port of the diplexer leads to coupling problems.

The doubler circuits were built separately, biased and tuned for maximum efficiency at 200 and 400 GHz input frequency, respectively. The efficiencies obtained were 54 percent and 50 percent, at two watts input to the first doubler, with the largest harmonic in the output more than 40 db below the second harmonic. The two doublers were then placed in cascade, and with a slight amount of tuning, mostly on the 400-800 GHz doubler, an efficiency of 28 percent was obtained for two watts input power. This tuning was required to adjust to the exact power levels in the circuits, and to accommodate for the slight amount of mismatch which must have existed between the two doubler circuits. Again, the largest harmonic was 40 db below the second.

Double stub timers were then placed at the input and output of the multiplier configuration and tuned to the maximum efficiency of 28 percent. Attempts to cause oscillations to occur by mistuning one of the tuners were unsuccessful except for a tuning of the output tuner which reduced the output of the configuration by 30 db. The same result was obtained when both tuners were detuned. When a resistive termination of 600 ohms was placed at the output port there were no oscillations.

ACKNOWLEDGEMENT

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Reference 1 - A. I. Grayzel, D. Parker, "Conditions for Parametric Oscillations in an Abrupt Junction Non-Overdriven Varactor Doubler," Proc. IEEE Vol. 56 No. 9, Sept., 1959 pp. 1589-90.

Reference 2 - G. L. Matthaei, E. G. Crystal, "Multiplexer Channel Separating Units Using Interdigital and Parallel Coupled Filters, "IEEE Transactions on Microwave Theory and Techniques Vol. MTT-13 May, 1965 pp. 328-334.

Reference 3 - R. J. Wenzel, "Printed-Circuit Complementary Filters for Narrow Bandwidth Multiplexers," IEEE Transactions on Microwave Theory and Techniques Vol. MTT-16-3 March, 1968, pp. 147-157.

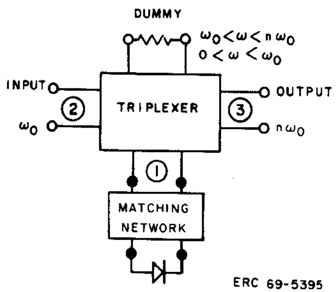

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Figure 1. Varactor Multiplier Using Four-Port Multiplexer for Stable Operation

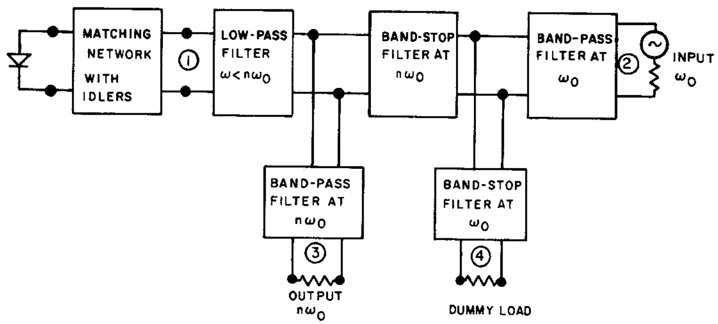

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Figure 2. Physical Realization of Figure 1

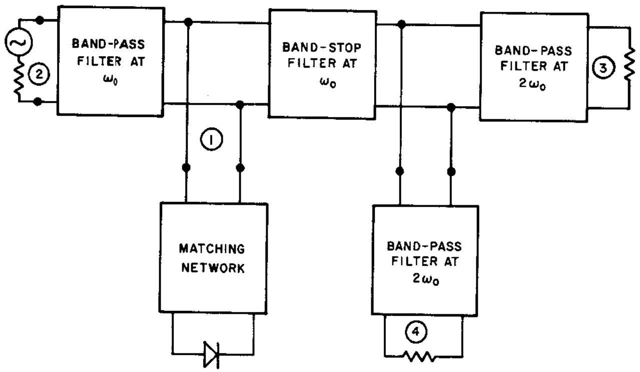

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Figure 3. Alternate Configuration Used for Experimental Models

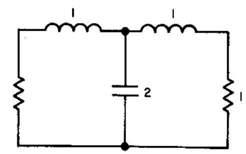

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Figure 4. Low-Pass Prototype Used for Design of Complementary Filters Used in Experimental Models