2.5 DESIGN THEORY OF UP-CONVERTERS FOR USE AS ELECTRONICALLY TUNABLE FILTERS*

George L. Matthaei
Stanford Research Institute
Menlo Park, California

The up-converters discussed use a single variable-capacitance diode, a wideband impedance-matching filter at the input, a moderately wideband impedance-matching filter at the pump input, and a narrowband filter at the side-band output. If f_0' is the frequency passed by the sideband filter, than for a lower-sideband up-converter,

$$f = f^p - f_0' \tag{1}$$

must be satisfied, where f is the input signal frequency and f^p is the pump frequency. If the pump frequency f^p is varied, the input frequency f that will be accepted also varies, as indicated by Equation (1). For an upper-sideband up-converter the relation

$$f = f_0' - f^p \tag{2}$$

holds where in this case f_0' is the upper-sideband frequency passed by the narrowband output filter.

Both the lower- and upper-sideband types of up-converters have a component of gain proportional to the ratio of the sideband output frequency to the signal input frequency, but the lower-sideband type gives additional gain due to its negative-resistance properties. By keeping the negative resistance portion of the gain low, good stability should be possible. By analytical methods similar to those in Ref. 1, it is shown that wide tuning range is possible using either type of device.[2] Making the sideband output filter of narrow bandwidth makes it possible for the input impedance-matching filter to be quite broadband, which in turn permits a large tuning range. It will generally be necessary to accept a reflection loss of a number of db at the pump channel, but by use of an impedance-matching filter, this reflection loss can be kept nearly uniform across the band. The incident pump power required should be within the range of available, voltage-tunable microwave oscillators.

Figure 1 shows a proposed circuit which was used in analyzing the performance of possible amplifiers of this type. Resonators X_3 and B_2 on the left resonate at the center of the input-frequency band, while resonators B_2^p and X_3^p on the right resonate at the center of the pump-frequency band. The series-connected diode along with the high-Z_0 line make up a circuit which looks like a series resonator both at the center of the input frequency band, and again at the center of the pump-frequency band. The loosely coupled sideband resonator resonates at the sideband frequency, f_0', and brings the diode circuit to a narrow resonance at the frequency.

Figure 2 shows a possible stripline realization of the circuit in Fig. 1. Input resonators 2 and 3 are realized as semi-lumped, shunt resonators separated by a quarter-wavelength line. The pump-channel resonators are realized in cascaded, quarter-wavelength resonators as discussed in Ref. 3. The diode is in a computer-type package and the leads provide the high-Z_0 line. The sideband resonator is of the quarter-wavelength type with inductive coupling to the diode lead wire and capacitive coupling to the output line.

Design theory and charts are presented for both the lower-sideband and upper-sideband types of devices. Performance estimates of several trial designs based on the circuit in Fig. 1 are presented. These estimates indicate that properly designed devices of this type using voltage-tunable pump oscillators should have tuning ranges of the order of a half-octave to an octave, fast tuning capability, a useful amount of gain, no image response, and a low noise figure.

---

*This research was sponsored by the U. S. Army Research and Development Laboratory, Ft. Monmouth, N. J. under Contract DA 36-039 SC-74862.

[1] G. L. Matthaei, "A Study of the Optimum Design of Wide-Band Parametric Amplifiers and Up-Converters," IRE Trans. PGMTT, vol. MTT-9, pp. 23–38, (January 1961).

[2] G. L. Matthaei, "Design Criteria for Microwave Filters and Coupling Structures," Technical Report 11, SRI Project 2326, Contract DA 36-039 SC-74862, Stanford Research Institute, Menlo Park, California (September 1960).

[3] G. L. Matthaei, "Direct-Coupled, Band-Pass Filters with $\lambda_0/4$ Resonators," 1958 IRE National Convention Record, Part 1, pp. 98–111.

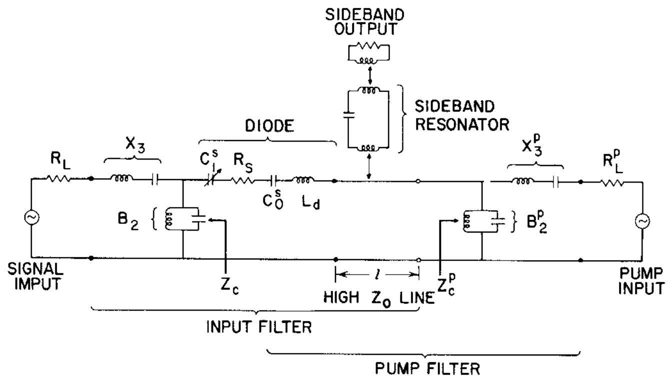

Figure 1 - A Possible Circuit for an Up-Converter for Electronically Tunable Filter Applications.

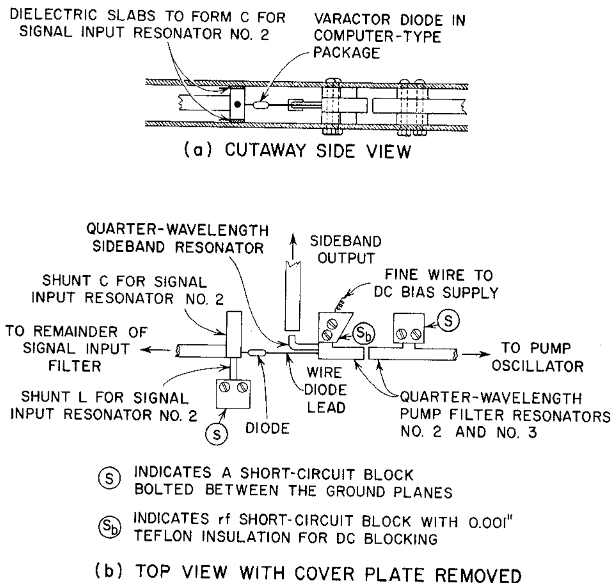

Figure 2 - A Possible Strip-Transmission-Line Embodiment of the Circuit in Figure 1.