II-7. FILTER-DIODE INTEGRATION

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Integration of a semiconductor diode within a microwave filter circuit may result in superior performance over separate components. This paper will consider several classes of devices which yield electrical and mechanical characteristics impossible to obtain by the separate treatment of individual components.

The Directional Filter-Mixer. The directional filter combines the properties of a directional coupler and a bandpass filter. It is a four-port device in which the input signal emerges from an arm with the frequency response of a bandpass filter while the remaining power emerges from another arm with the complementary response of a band rejection filter. The input is matched both at resonance and off resonance. The fourth arm is isolated from the input arm at all frequencies. These properties make it ideal for combining a signal and a local oscillator in one port for mixing in a crystal diode.

The characteristics that are afforded to the directional filter-mixer fall into two groups depending on whether the signal or local oscillator is filtered through the bandpass filter portion.

A. Signal passed through the bandpass filter portion.

1. Local oscillator radiation is suppressed by the bandpass filter.
2. Local oscillator noise about the signal frequency (not the image) is coupled to the load.
3. The image frequency couples into the local oscillator port (may be terminated if an isolator is used).
4. The local oscillator power is coupled efficiently to the diode.
5. The fourth port may be used for a transmitter if the receiver and transmitter are of different frequencies. The signal arm may then be used as the antenna port.

B. Local Oscillator passed through the bandpass filter portion.

1. Local oscillator radiation is suppressed by the band reject filter portion and by the directivity of the bandpass response.
2. Local oscillator noise about the signal and image frequencies is suppressed.
3. The image frequency couples to the signal port.
4. The local oscillator power is coupled efficiently into the diode degraded by the insertion loss of the filter.

In both cases, high i-f frequencies may be employed. This device may also be used as an up-converter circuit. Gain may be obtained over a broad band of input frequencies when a variable frequency pump is used. The desired output is coupled at a single frequency with low loss by the bandpass filter.

Figure 1 shows four directional filter-mixers (frequency translators). Two of these devices are microwave mixers in the C-band region. One is stripline and the other waveguide. The typical noise figure is 7.2 db into a 1.5 db i-f noise figure. The third device is a directional filter up-converter where a broad band of input frequencies (100-1200 mc) is up-converted to 9000 mc by using a variable frequency pump (9100-10,200 mc). The fourth device is an up-converter with a fixed pump at 14 gc, an input frequency 2-4 gc, and the output 10-12 gc.

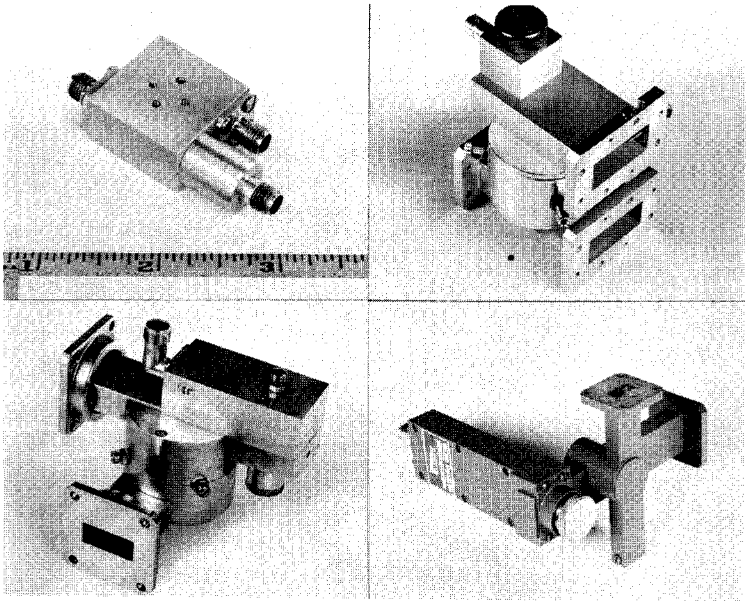

Figure 1. Four Types of Directional Filter-Mixers

The Interdigital Diplexer-Mixer. The basic form of the interdigital and combline bandpass filter is ideal for frequency diplexing by arranging two filters such that they share a common input. In general, the length of the input section is one-quarter wavelength at the design frequency. If a microwave diode is placed at this junction, a signal and local oscillator may efficiently be coupled to it through the bandpass filters. For low intermediate frequencies the image frequency generated in the diode is terminated in an open circuit produced by the quarter wavelength shorted input section. Thus, superior conversion loss is obtained. In some applications, particularly in frequency translation, where the local oscillator frequency is lower than either the signal or i-f, the local oscillator signal may be coupled in with a low pass filter located inside the input section. Such a device is quite efficient and provides very high isolation between input and output.

Figure 2 shows an interdigital diplexer-translator which translates the 1700-1900 mc band to the 2200-2400 mc band with less than 6 db conversion loss and greater than 60 db rejection of unwanted sidebands. The flatness of loss over this frequency band is within 0.5 db.

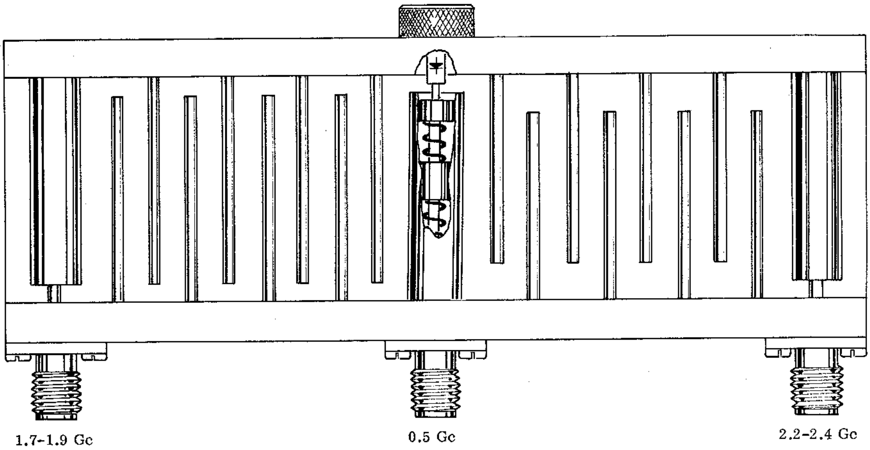

Figure 2. Interdigital Diplexer Translator

For applications in which the local oscillator is the same frequency as the transmitter, a different configuration can be used. This is shown in Figure 3, which shows a combline diplexer-mixer which serves as the r-f front end for a transponder. It is a transmit-receive diplexer with a single-ended mixer at the end of the receive filter. Local oscillator injection is provided by leakage of the transmit frequency (2304 mc) through the two-section receive filter and is controlled by a variable band reject filter section. The five-section transmit filter provides greater than 60 db isolation at the receive frequency (2376 mc). The noise figure is 7 db (1.5 db noise figure, 72 mc i-f).

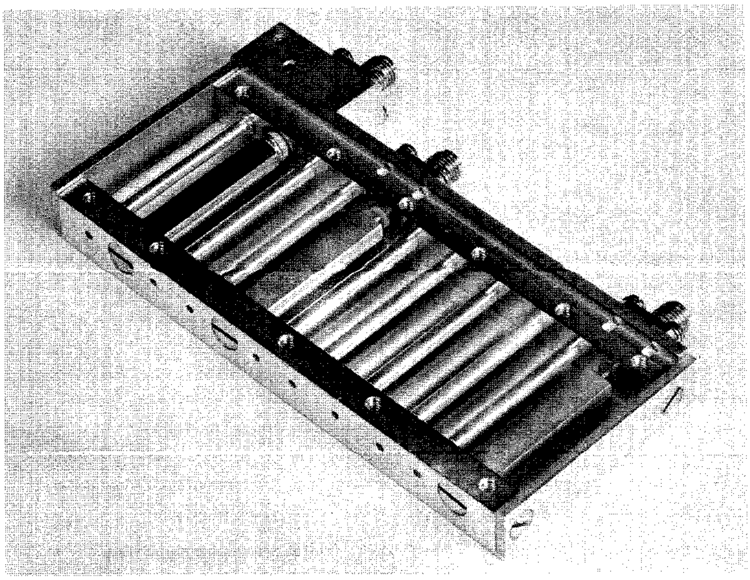

Figure 3. Combline Diplexer-Mixer

Dual Interdigital Diplexer Frequency Translator. In repeater applications where weight and power are at a premium, the use of a re-entrant TWT amplifier can be advantageous. In this arrangement a signal is amplified by a TWT, then converted to another frequency within the TWT operating band, and then amplified by the TWT again. The overall gain is twice that of the TWT, less the loss in the converter. The r-f circuitry required for this method is usually fairly complex and cumbersome, consisting of couplers, filters, circulators, and a mixer. The proper integration of filters and a diode, however, allows the use of a single component to perform all the necessary functions.

This single component, the dual interdigital diplexer frequency translator, is shown in Figure 4. The unit is actually a diplexer-frequency translator, as described above, combined with two additional filters through diplexing junctions. The 2 gc local oscillator is introduced to the junction through a low-pass filter. The converted signal passes through the "inside" 4 gc filter, through the TWT, and through the 4 gc output filter. The package can be constructed such that it mounts directly to the TWT, making a single, compact assembly.

A unit was constructed at C-band which converts the 5925-6425 mc band to the 3700-4200 mc band with 8 db conversion loss and isolation of greater than 80 db between channels. The local oscillator frequency was 2225 mc which has no harmonics within the signal bands.

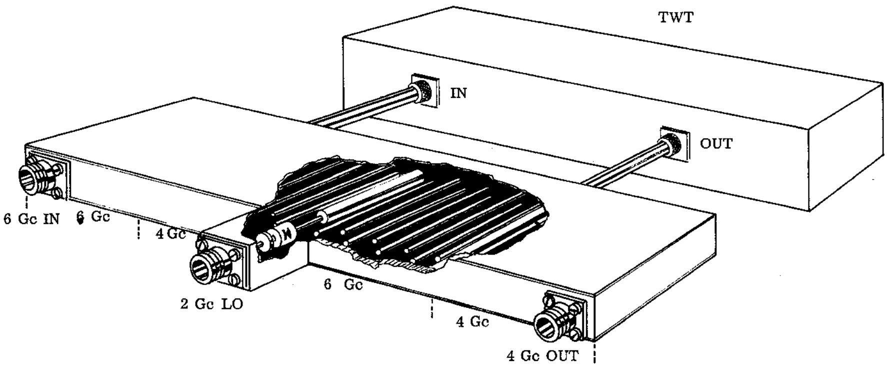

Figure 4. Dual Interdigital Diplexer Frequency Translator

The Orthogonal Mode Mixer - Combline Filter. If a pair of diodes are placed between the coupling section and ground planes of a combline filter then the diodes are excited 180 degrees out of phase. A signal filter is then constructed so that its output is coupled to the diodes. A waveguide whose dominant mode electric field is coupled to the diodes from the other side of the filter in such a manner that the diodes are excited in phase is used and the i-f is brought through the base of the input transformer by means of a low pass filter. Figure 5 shows the configuration of the mixer-filter. The dimensions of the filter are such that the waveguide mode will not propagate, so that the general properties associated with the diplexer-mixer are obtained. The typical noise figure and VSWR are similar to orthogonal mode mixers allowing for inspection loss of the filter and the improvement due to an open circuit image frequency termination. Hot carrier diodes due to their small size and low r-f impedance are used in this device.

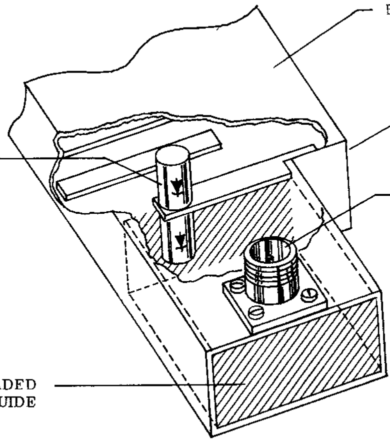

Figure 5. Orthogonal Mode Mixer - Combline Filter