II-6. BROADBAND FREQUENCY TRANSLATORS

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Introduction. In most microwave systems signals are converted from one frequency to another -- usually from microwave to conventional intermediate frequencies from 30 - 200 MHz. However, there is a large class of systems which employ microwave translators which convert from one microwave frequency to another. This paper will deal with microwave frequency translators in which the bandwidth of these signals is large -- usually greater than an octave and up to a decade.

Several system applications are presented for broadband translators, followed by devices which have been designed to meet system specifications.

A broadband receiver covering a decade in frequency may be realized by the use of a broadband frequency translator. The input may be up-converted to a fixed intermediate frequency with a variable frequency local oscillator, or pump. Large tuning range and excellent dynamic range may be obtained by this method. Other examples of system uses of frequency translators are found in wide bandwidth radar and telemetry systems, and are shown in Figure 1. A frequency scanning antenna radar system may use correlation techniques which mix two wide bands of microwave signals such that the desired output is at a single frequency. The signal processing systems such as satellite communications and microwave links require microwave frequency offsets. In the instrumentation field a laboratory swept signal generator may be translated to another frequency band.

The system application determines such basic factors as conversion loss, noise figure, and input match. There are two other very important parameters which may be specified: 1) Dynamic range --either spurious-free dynamic range or saturation of the output with respect to the input; and 2) Phase response -- usually the variation of linearity of the phase of the output with respect to the input.

The dynamic range of the translator is usually a stringent requirement since often the bandwidths are much greater than an octave and the second or third harmonics of the signal or local oscillator may be within the desired output band. While in some systems a judicious choice of frequencies eliminates some of the problems, it may be necessary to use balanced configurations or filtering to improve the dynamic range. Dynamic range may also be improved by using a high level local oscillator at some sacrifice in noise figure (although not necessarily in translators using varactors).

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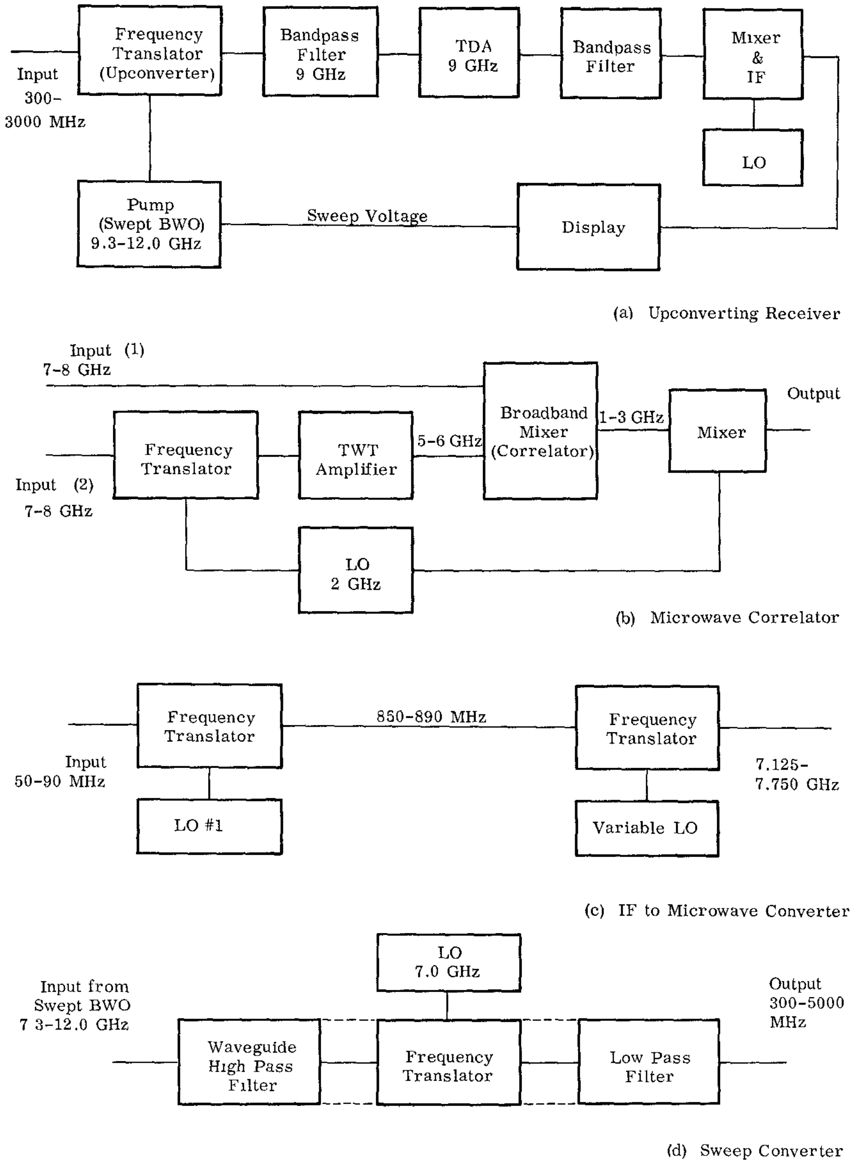


Figure 1 SYSTEM APPLICATIONS OF FREQUENCY TRANSLATORS

The phase response of a translator when used in FM and PM systems should be kept linear so that distortion is maintained at a low level. Phase linearity is often difficult to obtain because of the requirement of low spurious outputs and hence the necessity for filtering, which usually produces phase distortion. The reflections in such systems must be kept small to keep delay distortion at a low level. The general technique involved is to separate the frequency components (signal, pump or local oscillator, and output or intermediate frequency), by filtering or balancing so that each component is efficiently coupled to the diode. The use of low-pass, band-pass, and band-rejection TEM-type filters together with waveguide (with its high-pass filter characteristic) is shown in the following examples.

I. Broadband Receiver Front End. This unit was designed for a 300 - 3000 MHz swept frequency receiver. The pump was 9.3 to 12.0 GHz and the output signal was 9.0 GHz. Since dynamic range was a serious consideration, the unit employed balanced varactors. The input signal was coupled through a multi-section low pass filter to the center of the varactor pair. The pump section was low impedance waveguide and the output was a band-pass filter at 9.0 GHz. The reference planes of the low pass filter and band-pass filter were chosen so that each reflected an open circuit within the passband of the other. The impedance of this device viewed at the diode mount was relatively low. The waveguide impedance was less than 100 ohms, while the signal and output impedances were 5 - 25 ohms. The design of the filters needed to achieve these impedances was relatively straightforward. Experimental results of this device are as follows:

Input Frequency	300 - 3000 MHz
Pump Frequency	9.3 - 12.0 GHz
Pump Power	+ 24.3 dBm
Output Frequency	9.0 GHz
Output Bandwidth	30 MHz
Conversion Gain	0 dB at 300 MHz -1 dB at 3 GHz
Noise Figure (with 10 dB 2nd stage NF)	11 dB typ., 13 dB max.
Dynamic Range	70 dB
Pump Power at Signal Input	= 70 dB down
Pump Power at Output Port	= 70 dB down

A matched (within 10%) pair of varactor diodes having a 200 GHz minimum cutoff frequency was used. The balance of the diodes alone to the pump source at the output frequency was of the order of 30 dB. A photograph of this unit and its curve of gain vs frequency is shown in Fig. 2.

II. Microwave Correlation. This type of device has a wide input signal band and a wide local oscillator band, but a wider output band. An input frequency of 7 - 8 GHz was mixed with an L.O. of 5 - 6 GHz, using a balanced configuration because of the need for good dynamic range. Hot carrier or Schottky-barrier diodes were used to keep the impedances at workable values and to provide good dynamic range when pumped at +13 dBm. The signal was injected through ridge waveguide, and the local oscillator was introduced through an eight-section band-pass interdigital filter which provided filtering of the input band. The output was a nine-section low-pass filter with cutoff at 3.125 GHz. Typical conversion loss was 8 dB and the input match in both the L.O. and the signal ports was less than 1.5 VSWR. The spurious level at an input signal level of +5 dBm was -25 dBm. This is somewhat better than can be obtained with point contact silicon mixer diodes. A photograph of the unit is shown in Figure 3.

III. Phase Linear Frequency Translator. In FM and PM systems, the microwave signals are often derived by up-converting signal bands in the VHF region. It is important that spurious signals be kept at a minimum while maintaining a high degree of phase linearity. A device shown in Figure 4 was used to convert the frequency band 50 - 90 MHz (at -5 dBm) to 850 - 890 MHz by an 800 MHz local oscillator (at +12 dBm). The use of band-rejection filters allowed attenuation of sidebands and did not produce phase nonlinearity or conversion loss variation of the desired signal. If reflective band-reject filters had been used, the sidebands would have been reflected back into the diode producing delay distortion. The input low-pass filter was designed to cut off far enough above the input frequency so as to cause negligible nonlinear phase shift within the signal band. Local oscillator power was introduced by means of a narrow band directional filter. A high-pass filter was used to terminate the input signal at the diode and to provide a d-c return. Band reject filters were used to terminate the second harmonic of the local oscillator and the lower sideband output.

This unit had approximately 7.5 dB conversion loss, and the variation in linearity over the entire frequency range was less than 2 degrees. These units were also used as down-converters. Final results are shown in Fig. 5. A silicon point contact diode was used in this application. When a Schottky-barrier diode was substituted and the pump power increased from +12 dBm to +25 dBm, the spurious level improved by 8 dB to 35 dB for the second order products, while the conversion loss was reduced to 6.2 dB.

IV. Sweep Converter. The backward wave oscillator used in commercial laboratory equipment is limited in frequency range to slightly greater than an octave. In some applications, where broadband devices are being tested, it is desirable to view on a swept display many octaves. Such a unit was built to convert the 7.3 to 12.0 GHz output from a conventional X-band swept source to 300 - 5000 MHz by mixing with a 7.0 GHz oscillator. It was constructed in waveguide using a bandpass filter tuned at 7 GHz with the proper reference planes so as to terminate the diode from 7.3 to 12.0 GHz. The output was filtered by a low-pass filter which terminated the diode in the 7 - 12 GHz range. Considerable problems were encountered in coupling the energy around 5 GHz due to the large discontinuity which the waveguide presented. This was reduced by a ridge structure reducing the waveguide size.

The dominant inband spurious outputs, 2 x (signal) - (L.O.) and 2 x (signal) - 2 x (L.O.) were 15 dB below the desired output. The spurious output caused by 2 x (L.O.) may be reduced by providing a choke arrangement at the base of the diode mount to reflect an open circuit at the diode junction so that no currents flow at the second harmonic. Another 10 - 15 dB rejection may be obtained in this manner. When used as a laboratory device, the unit may be levelled by feedback to the swept oscillator. Without levelling, flatness is ±1.5 dB at an output level of -10 dBm.

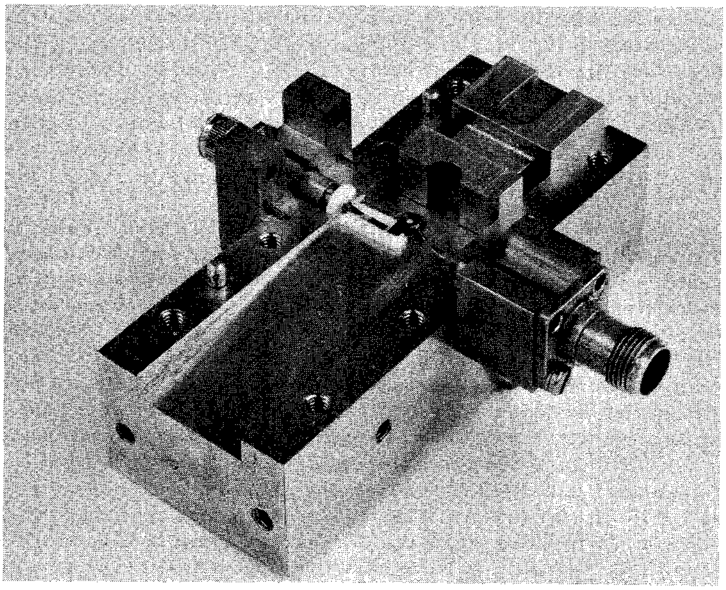


Figure 2 (a) -
PARAMETRIC UPCONVERTER

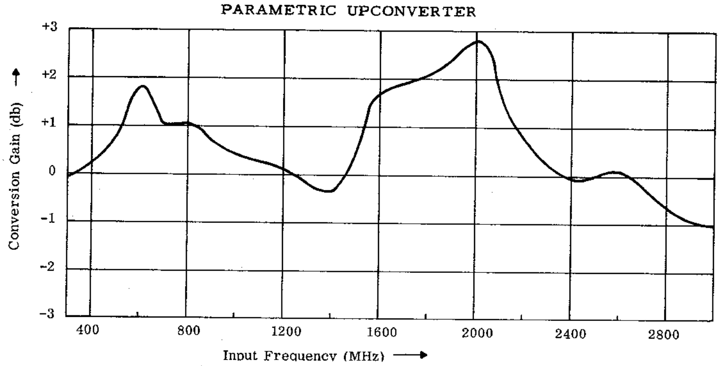
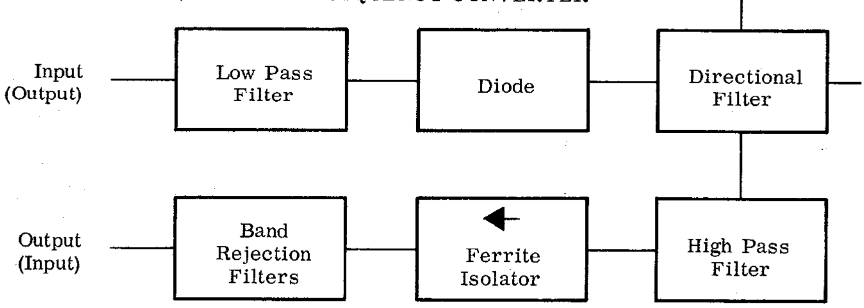


Figure 2 (b) - PARAMETRIC UPCONVERTER RESPONSE

Figure 4 (a)

BLOCK DIAGRAM, TYPICAL FREQUENCY CONVERTER



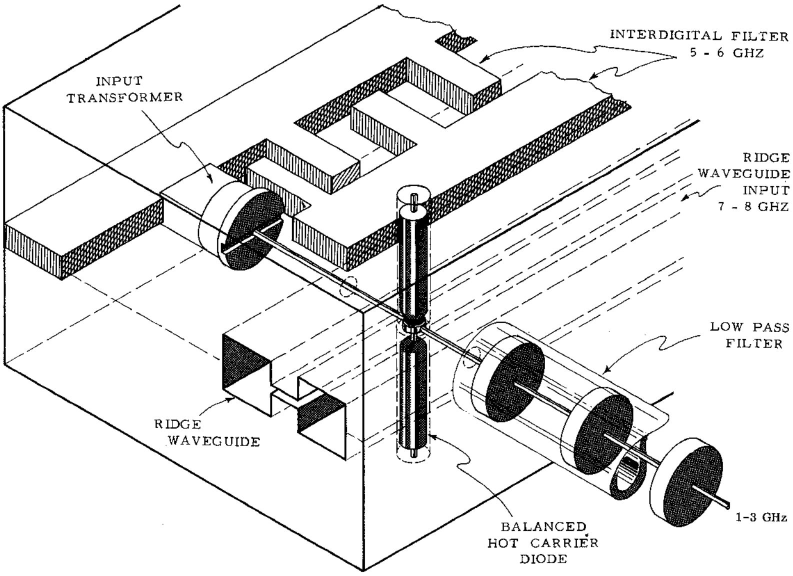


Figure 3. Microwave Correlator

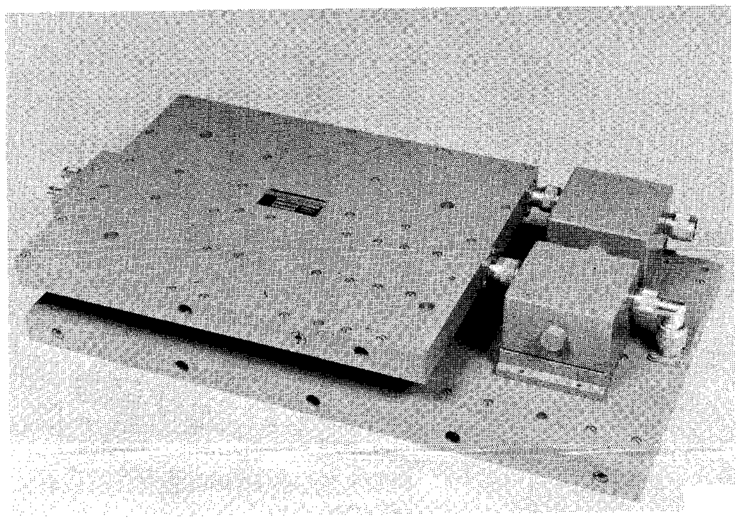


Figure 4b. Upconverter With Band Rejection Filters

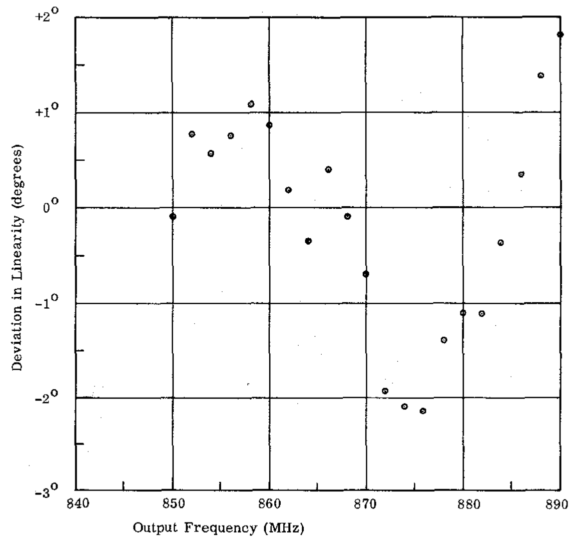


FIGURE 5
PHASE LINEARITY OF FREQUENCY TRANSLATOR

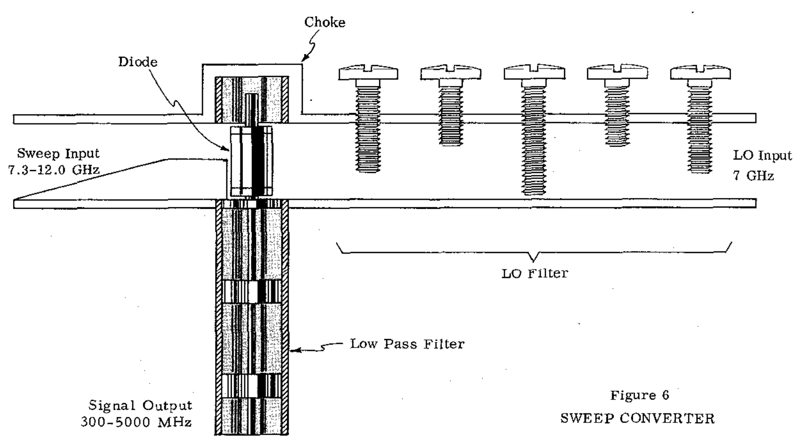


Figure 6
SWEEP CONVERTER

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