DUAL CHANNEL MIXER

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A dual channel, phase-locked mixer was constructed to convert 278 kHz to 20 kHz in a microwave power calibrating system. Each circuit contains matching networks, mixer, amplifier, filter, load, and separate power supply.

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SUMMARY

A precise vector voltmeter (Princeton Applied Research Model 129, operated in the two-phase lock-in amplifier mode) is used in a microwave power calibrating system to accurately measure the outputs of a network analyzer (Hewlett Packard Model 8410 with Model 8411A harmonic frequency converter and Model 8413A phase-gain indicator). The validity of the measured outputs depends on the accurate representation of the network analyzer output (278 kHz) at a lower frequency (20 kHz) with sufficient signal level for proper operation of the vector voltmeter. A dual-channel mixer was constructed to convert 278 kHz to 20 kHz without loading the output ports of the network analyzer or local oscillators. In addition to being properly matched to the remaining circuitry, the mixers are driven in their linear region.

DISCUSSION

SCOPE AND PURPOSE

The Hewlett-Packard 8410A Network analyzer system is the primary measuring instrument used in a new microwave power measuring system in the Bendix Kansas City Division Metrology Laboratory. To transform phase and amplitude information to vector quantities needed for the computer data reduction program, a frequency conversion unit and vector voltmeter are needed.

The following design goals for the frequency conversion unit were established:

- Dual channel phase-locked frequency conversion from 278 kHz to 20 kHz;
- No loading of the network analyzer reference and test ports or of the local oscillator output ports;
- Reference output signal to the phase-locked vector voltmeter of at least 1 volt AC peak-to-peak; and
- Mixers local oscillator input of +7 to +10 dBm.

PRIOR WORK

A 278 kHz to 20 kHz down converter was constructed by Sandia Primary Standards Laboratory microwave section for their use in a similar microwave power measurement system. Impedance matching transformers were used to connect the local oscillator and network analyzer ports to the mixers. The channels were separated and each integral port connected with type N connectors and solid coaxial conductor. Local oscillators were synchronized by an interconnecting resonant frequency circuit. Units constructed in this manner are limited in their ability to match the varying output port impedance of the network analyzer and to provide enough signal in the reference channel to operate the vector voltmeter for maximum efficiency. This type of operation could limit the usable range of the network analyzer and the accuracy of the vector voltmeter.

ACTIVITY

Each channel of the mixer consists of two buffer circuits, a mixer unit, 50-ohm load, amplifier, and 20 kHz low pass filter (Figures 1 and 2). Balanced mixers (Merrimac Model DM-2-25 were

Figure 1. Dual Channel Mixer (Front View)

Figure 2. Dual Channel Mixer (Rear View)

used to convert the 278 kHz network analyzer output to the 20 kHz input required by the vector voltmeter. Isolation between all mixer ports is greater than 20 db and the conversion loss is approximately 7 db. These mixers have nominal impedance of 50 ohms. A buffer circuit was used to match the outputs of the network analyzer and slave oscillators to the mixer units (Figure 3). A load of 10 kilohms or greater was recommended by the manufacturer to assure that the network analyzer was not affected over its wide frequency range. Because the mixers are driven by the local oscillator input signal, a current source was needed. The needed current drain on the slave oscillators caused distortion, and again the buffer circuits were put to use but at a slightly lower frequency (258 kHz).

The buffer amplifiers (National Semiconductor LH0033) provide FET (10^{10} ohms) input impedance and were designed to operate into the 50-ohm mixer circuit. The buffers are high speed voltage followers which provide high current drive as well as excellent phase linearity at 278 kHz, which is the output frequency of the network analyzer. Short circuit protection was added by inserting a 2-watt, 100-ohm current limiting resistor between the V and V_C pins. The V_C pins were then decoupled from the ground plane by 0.1 microfarad disc capacitors to regain the full output voltage swing for transient pulses. Both buffers were encased in shielded black boxes to provide ground plane shielding and minimize input capacitance.

The intermediate frequency output of the mixers was loaded with a 50 ohm feedthrough, then amplified. A frequency-compensated operational amplifier integrated circuit (Fairchild Model $\mu A741$) was used as the primary component in the amplifier circuit, Figure 4. This operational amplifier is used in a non-inverting configuration with an input resistor of approximately 900 ohms and a voltage divider circuit of a 1 kilohm fixed and 10 kilohm variable feedback resistor for gain control. The gain, adjusted for maximum, is approximately 8.

The output of the amplifier passes through a 20 kHz low pass filter (Figure 5) to reduce high frequency signals and noise present as a result of the mixing process. The filter elements are enclosed in a shielded black box with the ground plane attached to the box. The resistor elements are metal film for good temperature stability and the capacitors are mica because of their low dissipation and excellent stability with time and temperature. Outputs from the reference and test channels of the mixer circuits are connected directly to the reference and signal ports of the vector voltmeter respectively.

Figure 3. Buffer Amplifier Schematic

Figure 4. Amplifier Schematic

Figure 5. 20 kHz Low Pass Filter Schematic

A soft iron core toroid was added to the test channel connecting cable to reduce possible AC ground loops and pickup noise.

Figure 6 is a complete mixer block diagram showing the chassis layout with power supplies, switch, and indicators. Table 1 lists calculations used to determine the power level needed and used to operate the mixers correctly. Table 2 is a procedure and data list of the tests run on the completed mixer assembly. The tests were run in the following manner. Power output to an "unknown" test port on a 1.0 to 2.0 GHz reflectometer head was set to 1 mW microwave power at approximately 1.1 GHz with a Hewlett Packard 432A series power meter and a Hewlett Packard 478A thermistor mount. This caused the Hewlett Packard 8410A network analyzer to operate in the proper range to produce a 278 kHz signal from its rear test and reference ports. The test channel gain was set to 35 dB gain (normal operation) and the thermistor mount was then replaced with a short circuit to produce a higher amplitude test channel signal.

Table 1. Power Level Calculations

P = Power V = Voltage R = Resistance

$$\text{dB} = 10 \log P_2/P_1 = 20 \log V_2/V_1$$

$$V \text{ reference} = \sqrt{50\Omega \times 1\text{mW}} = 0.2236\text{V}$$

$$\text{dBm} = +7 = 20 \left[\log (V_2/0.2236) \right], V_2 = 0.50\text{V}.$$

$$0.50 V_{\text{rms}} = 1.4 V_{\text{p-p}}$$

$$\text{dBm} = +10 = 20 \left[\log (V_2/0.2236) \right], V_2 = 0.71\text{V}.$$

$$0.71 V_{\text{rms}} = 20 V_{\text{p-p}}, 1.5 V_{\text{p-p}} = 0.53 V_{\text{rms}}$$

$$\text{dBm} = 20 \log (0.53/0.2236) = +7.5$$

Figure 6. Dual Channel Mixer Block Diagram

Table 2. Operating Checkout

Test Point	Reference Channel	Test Channel
A (SET)	$3 \times 0.5V. = 1.5V$ (SET)	$3 \times 0.5V. = 1.5V.$
B	$2.6 \times 1.0V. = 2.6V$	$2.9 \times 1.0V. = 2.9V.$
C	$2.2 \times 0.5V. = 1.1V$	$2.5 \times 5 \text{ mV} = 12.5 \text{ mV}.$
D	$2.2 \times 0.5V. = 1.1V$	$2.2 \times 5 \text{ mV} = 11 \text{ mV}.$
E	$3.8 \times 2.0V. = 7.6V$	$4 \times 20 \text{ mV} = 80 \text{ mV}.$
F	$2.4 \times 1.0V. = 2.4V.$	$2.5 \times 10 \text{ mV} = 2.5 \text{ mV}$

All test data was taken with a Tektronix 545 oscilloscope utilizing a 1A7A plug-in with 3 dB points set to dc and 1 MHz. This combination is certified to an accuracy of ± 3 percent. Input impedance is 1 megohm in parallel with 47 picofarads. To make the measurements, a BNC "T" is inserted into the line, (with scope attached by BNC coaxial cable) at the point of measurement. Each channel is measured separately while it is completely active and loaded at all times during measurement.

The mixers used require a local oscillator frequency amplitude of 7 to 10 dBm into 50 ohms to operate correctly. Therefore, the first step was to set the amplitude of the local oscillator signals to 1.5 VAC peak-to-peak, (approximately +7.5 dBm, Test Point "A") into the mixers. This resulted in an output setting on the slave oscillators (phase-locked individual local oscillators, Test Point "B") of 2.6 and 2.9 volts peak-to-peak. Output of the buffer from the network analyzer reference channel was slightly greater than 1 VAC peak-to-peak, (Test Point "C"). Output of the buffer from the network analyzer test channel was 12.5 mVAC peak-to-peak, with all conditions as set forth above. The next point of insertion (between 50 ohm load and input of the amplifier, Test Point "D") produced a 20-kHz sine wave with the local oscillator and radio frequency riding on top of it, the amplitude was slightly decreased from the radio frequency input. Output from the amplifier produced a much cleaner 20-kHz signal with greater amplitude (gain of each amplifier was set to maximum--approximately eight times, Test Point "E"). The filter section effectively removed high frequency signals and noise and provided a 2.4 VAC peak-to-peak signal on the reference channel, Test Point "F" (well above design goals) and a 25 mVAC peak-to-peak signal on the test channel.

ACCOMPLISHMENTS

A dual-channel mixer assembly has been constructed and tested. Design goals set forth have been met or surpassed. The local oscillators have been locked together by a third digitally controlled oscillator via the synchronization ports and are isolated from the output of each other by the oscillation circuits themselves. The amplifiers in the intermediate frequency sections of the mixer circuit act as first stage low pass active filters due to their 100-kHz bandwidth. The unit constructed is presently being used in the development of a new power calibration system and appears to be performing as well as expected over the entire frequency range of the system (0.5 GHz to 8.0 GHz).

FUTURE WORK

Future work should include a study of the stability of the mixer channels with ageing and the accuracy with which the test channel will reproduce very small signals. The completed power calibration system will be checked to determine amplitude and phase linearity.

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