Two stages of mixers

1,031,500 input
1,020,000 1st pair of mixers
13,000 2nd pair of mixers
20,000 to 200,000 1st pair of filters
2,000 to 20,000 2nd pair of filters

Both I & Q are 1,500 Hz, 170 mv peak, but differ in phase by 180 degrees. The circuit output is less than 95 microvolts peak.
Circuit changed to
1,031,500 input
1,020,000 1\textsuperscript{st} mixer
10,000 2\textsuperscript{nd} mixer

Both I & Q are 1,500 Hz, 170mv peak, but differ in phase by 180 degrees. The circuit output is less than 140 microvolts peak.

Investigate signals with frequency lower than that of the 1\textsuperscript{st} mixer.
1,008,500 input
1,020,000 1\textsuperscript{st} pair of mixers
13,000 2\textsuperscript{nd} pair of mixers
20,000 to 200,000 1\textsuperscript{st} pair of filters
2,000 to 20,000 2\textsuperscript{nd} pair of filters
Both I & Q are 1,500 Hz, 170 mv peak, but differ in phase by 180 degrees. The circuit output is less than 95 microvolts peak.

Circuit output signal is 340 mv peak.

Conclusion
Signals having a frequency less than that of the 1<sup>st</sup> mixer will produce an output signal. Signals having a frequency greater than that of the 1<sup>st</sup> mixer will produce nearly zero output.

Investigate waveform details,
Now, change input frequency to 1,031,500
Continuing with 1,031,500

Now back to 1,008,500
\[ \sin \theta \sin \varphi = 0.5 \cos(\theta - \varphi) - 0.5 \cos(\theta + \varphi) \]
$$\sin \theta \sin \phi = 0.5 \cos (\theta - \phi) - 0.5 \cos (\theta + \phi)$$

$$\sin 2\pi f_{i1} t \sin 2\pi f_{i2} t = 0.5 \cos 2\pi (f_{i1} - f_{i2}) t - 0.5 \cos 2\pi (f_{i1} + f_{i2}) t$$

$$\sin (2\pi f_{i1} t + \pi / 2) = \cos 2\pi f_{i1} t$$

$$\sin \theta \cos \phi = 0.5 \sin (\theta + \phi) + 0.5 \sin (\theta - \phi)$$

$$\sin 2\pi f_{i1} t \cos 2\pi f_{i2} t = 0.5 \sin 2\pi (f_{i1} + f_{i2}) t + 0.5 \sin 2\pi (f_{i1} - f_{i2}) t$$

Dropping the high frequency terms (filtering) leaves,
$$0.5 \sin 2\pi (f_{i1} - f_{i2}) t$$
and $$0.5 \sin 2\pi (f_{i1} - f_{i2}) t$$

The next step involves the 2\textsuperscript{nd} local oscillator,
$$\sin 2\pi f_{i1} t \cos 2\pi f_{i2} t = 0.5 \sin 2\pi (f_{i1} + f_{i2}) t + 0.5 \sin 2\pi (f_{i1} - f_{i2}) t$$

and
$$\sin (2\pi f_{i1} t + \pi / 2) = \cos 2\pi f_{i1} t$$

$$\sin 2\pi f_{i2} t \cos 2\pi f_{i1} t = 0.5 \sin 2\pi (f_{i1} + f_{i2}) t + 0.5 \sin 2\pi (f_{i1} - f_{i2}) t$$

Inserting the example frequencies for input 1008500,
$$0.5 \sin 2\pi (13000 + (1008500 - 1020000)) t$$
and $$0.5 \sin 2\pi (1008500 - 1020000 + 13000) t$$

$$0.5 \sin 2\pi (1500)$$
$$0.5 \sin 2\pi (-1500)$$

Inserting the example frequencies for input 1013500,
$$0.5 \sin 2\pi (13000 - 1031500 + 1020000)$$
and $$0.5 \sin 2\pi (1031500 - 1020000 - 13000)$$

$$0.5 \sin 2\pi (1500)$$
$$0.5 \sin 2\pi (-1500)$$
MIXERS

Input freq higher than mixer frequency.
Mixer $+\pi/2$. Output lags compared to Mixer $+0$

Input freq higher than mixer frequency.
Mixer $-\pi/2$. Output leads compared to Mixer $+0$

![Diagram of mixers with corresponding text](image-url)
Input freq lower than mixer frequency. 
Mixer $+\pi/2$. Output leads compared to Mixer $+0$

Input freq lower than mixer frequency. 
Mixer $-\pi/2$. Output lags compared to Mixer $+0$
Quadrature Phasing Detector - rejects interfering frequencies, those below the 1st mixer local oscillator frequency.
Detected waveform is 1500 Hz
Waveform math

1) 1st stage, upper mixer, 0 degree phase shift
\[ \sin \theta \sin \phi = 0.5 \cos(\theta - \phi) - 0.5 \cos(\theta + \phi) \]
\[ \sin 2\pi f_{in} t \sin 2\pi f_{lo1} t = 0.5 \cos 2(\pi f_{in} - f_{lo1}) t - 0.5 \cos 2\pi (f_{in} + f_{lo1}) t \]

2) 1st stage, lower mixer, \(-\pi/2\) degree phase shift
\[ \sin 2\pi f_{in} t \sin 2\pi (f_{lo1} t - \pi/2) = 0.5 \cos 2\pi (f_{in} - f_{lo1}) t + 0.5 \cos 2\pi (f_{in} + f_{lo1}) t - \pi/2) \]

Low-pass filters cancel the high frequency terms, leaving as inputs to the low-pass filters,
1) \[ 0.5 \cos 2\pi (f_{in} - f_{lo1}) t \]
2) \[ 0.5 \cos 2\pi (f_{in} + f_{lo1}) t + \pi/2) \]

The 2nd stage mixers outputs will be,
1) \[ 0.5 \cos 2\pi (f_{in} - f_{lo1}) t \sin 2\pi f_{lo2} t \]
2) \[ 0.5 \cos 2\pi (f_{in} - f_{lo1}) t + \pi/2) \sin 2\pi f_{lo2} t \]

\[ \cos \theta \sin \phi = 0.5 \sin(\theta + \phi) - 0.5 \sin(\theta - \phi) \]

This is,
1) \[ 0.25 \sin 2\pi (f_{in} - f_{lo1}) t - 0.25 \sin 2\pi (f_{in} + f_{lo1}) t \]
2) \[ 0.25 \sin 2\pi (f_{in} - f_{lo1} + f_{lo2}) t - 0.25 \sin 2\pi (f_{in} + f_{lo1} - f_{lo2}) t \]

Let \( f_{in} = 1031500 \quad f_{lo1} = 1020000 \quad f_{lo2} = 13000 \quad \text{and} \quad f_{in} - f_{lo1} = 11500 \)
1) \[ 0.25 \sin 2\pi (11500 - 13000) t + 0.25 \sin 2\pi (11500 + 13000) t \]
2) \[ 0.25 \sin 2\pi (11500 + 13000) t + \pi) - 0.25 \sin 2\pi (11500 - 13000) t \]

Low-pass filters with eliminate the higher frequency terms leaving,
1) \[ 0.25 \sin 2\pi (11500 - 13000) t = 0.25 \sin 2\pi (11500 + 13000) t \]
2) \[ 0.25 \sin 2\pi (11500 - 13000) t) = 0.25 \sin 2\pi (11500 + 13000) t \]

The waveforms when added double the output.

Let \( f_{in} = 1008500 \quad f_{lo1} = 1020000 \quad f_{lo2} = 13000 \quad \text{and} \quad f_{in} - f_{lo1} = -11500 \)
1) \[ 0.25 \sin 2\pi (-11500 + 13000) t + 0.25 \sin 2\pi (-11500 - 13000) t \]
2) \[ 0.25 \sin 2\pi (-11500 + 13000) t + \pi) - 0.25 \sin 2\pi (-11500 + 13000) t \]

Low-pass filters with eliminate the higher frequency terms leaving,
1) \[ 0.25 \sin 2\pi (-11500 + 13000) t = 0.25 \sin 2\pi (1500) t \]
2) \[ 0.25 \sin 2\pi (1500) t + \pi) \]

The waveforms cancel when added.