Complex Mixer System

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The complex mixer system is a signal preconditioner to a Fast Fourier Transform (FFT) power spectrum analyzer. It generates a complex time series output of the real-valued time series fed to its input. Two complex mixers have been constructed and installed at DSS 14. They have processed signals received from the Mariner 1971 spacecraft to investigate induced cross polarization of signals passing close to the solar corona.

I. Introduction

A new complex mixer system was installed in the pedestal control room at DSS 14. This system is an integral part of the R&D spectrum analyzer. The new system has an added 10-MHz input capability as well as a second channel. The two independent channels are able to accept either the 2.5- or the 10-MHz IF receiver outputs and have a maximum overall bandwidth of 100 kHz. This allows the spectrum analyzer to operate either with the experimental receiver/microwave link in the 2.5-MHz mode or the DSIF receiver in the 10-MHz mode.

The Mariner 1971 superior conjunction receiver experiment made use of the added capabilities of the system to simultaneously perform the S-band right- and left-circular polarization spectral measurements. Since the signal transmission path lay close to the sun, this experiment was designed to investigate the effect of solar corona turbulence on such signal characteristics as spectral broadening of the normal right-circular polarized signal component and inducement of a left-circular signal component.

II. System Description

Figure 1 shows a block diagram of the complex mixer system. In this figure, two separate channels are shown, each of them containing a relay box that selects either the experimental receiver/microwave link or one of the DSIF receivers (receivers 3 and 4). Following the relay box is a complex mixer module (CMM), which is the main topic of this report. The inputs of the CMM are the 5-MHz reference and the RF signal selected by the relay box. The outputs of the CMM are the real and imaginary components of the complex signal generated. These signals are sent through the variable filters which determine the overall bandwidth of the system. Following the filters are variable gain amplifiers needed to optimize the gain of the system.

III. Complex Mixer Module

A complex mixer module block diagram is presented in Fig. 2. This diagram shows that the RF input signal is applied to two separate channels. At the input of each channel there is a buffer amplifier needed to prevent

the modulation products generated by the mixers from contaminating the input source. These buffers also provide the 14 dB of attenuation necessary to operate the mixers linearly. The buffered RF input signal is then mixed with the locally generated sin $\omega_0 t$ and cos $\omega_0 t$ to shift the IF frequency ω_0 to baseband, and to produce at the same time the complex modulation products. These signals are then boosted by two 40-dB gain low-noise amplifiers whose $1/f$ noise figure is very low. Following the amplifiers there are active low-pass filters that allow the difference of the modulation products to go through, cutting off the sum products and all the harmonics. These active filters were designed to exhibit a two-pole Butterworth (maximally flat) response, with a cutoff frequency of 1 MHz. The outputs of the filters are then buffered by unity-gain power amplifiers able to drive 50-Ω coax cables terminated with 50-Ω loads. Capacitors are used to block the dc component.

The sin $\omega_0 t$ and cos $\omega_0 t$ are generated by a 2-flip-flop Gray code counter (sin/cos generator), driven by a 40/10-MHz clock. The outputs of this generator are the two buffered squarewave signals at 90-deg phase difference, with a frequency of one-fourth the input clock frequency.

IV. Phase-Locked Loop

The 40/10-MHz clock frequency input to the counter is generated by a phase-locked loop (PLL), whose block diagram is depicted in Fig. 3. The PLL is used instead of a much more expensive frequency synthesizer to generate the 40 or 10 MHz locked to the station standard needed to run the sin/cos generator. Figure 3 shows that preceding the PLL there is a Schmitt trigger detecting the 5-MHz station standard used as a reference. The output of the Schmitt trigger is then compared with the output of the feedback counter in a digital phase detector. Once the loop is operating in the phase mode, the output of this detector produces an analog error voltage proportional to the error in phase between the detected input reference and the countdown output frequency. The error voltage is then filtered by an active-

type filter that determines the loop bandwidth. The filtered error voltage is applied to the voltage-controlled oscillator. The loop is closed by the divide-by-four and divide-by-two counters, which allow the output frequency to be compared with the input reference, as explained above. Figure 3 also shows the switch that selects the 40- or 10-MHz clock output.

V. System Performance

Table 1 summarizes the typical characteristics of the complex mixer module. The phase relationships between the real and the imaginary outputs were measured with a Hewlett-Packard (HP) computing counter. In each complex mixer, the channels are balanced in gain to within 5% and in phase to within 6 deg over the entire operating bandwidth of 0.02 Hz to 1 MHz.

VI. Package

The complex mixer module is packaged in a newly designed RF standard DSN module, illustrated in Fig. 4. This figure shows three printed circuit sections, the phase-locked loop, the sin/cos generator, and the complex mixer itself. All the microcircuits are on sockets for easy field maintenance. Figure 5 shows the complex mixer front panel. The front panel has a receiver switch that controls the mode of operation as well as the relay box receiver selection. Two light-emitting diode (LED) indicators display the receiver mode selected by the receiver switch. The inputs and outputs to the unit are accessed through four connectors mounted on the front panel. This system, consisting of two complex mixer modules and a relay box, is housed in a DSN standard cage.

VII. Conclusion

Two complex mixer modules and a relay box were constructed to implement the system shown in Fig. 1. The system was installed in the pedestal control room at DSS 14 and successfully used to perform spectral measurements on signals from the Mariner 1971 spacecraft.

Table 1. Complex mixer module specifications

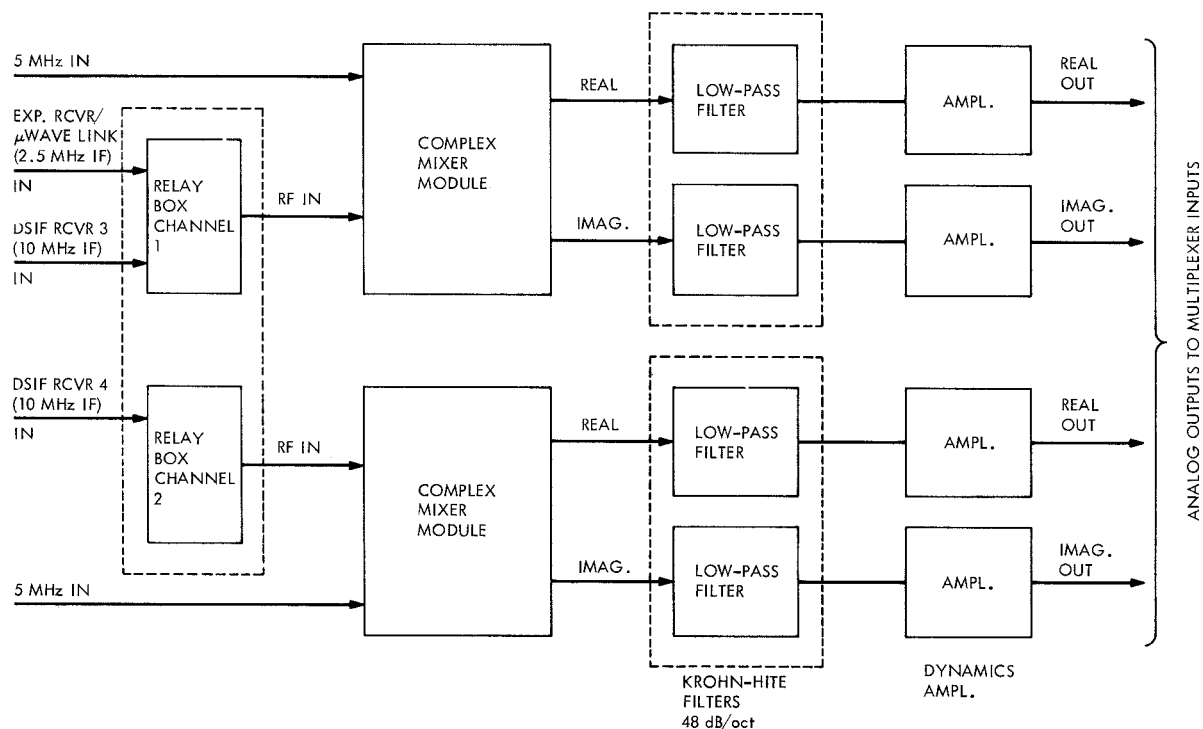| Parameters	Values	Comments
Input impedance	50 Ω	
Bandwidth	0.02 Hz – 1 MHz	When loaded with 10 MΩ
Phase tracking	< 6 deg	Phase difference between channels
Amplitude tracking	< 5%	
Maximum input power	4 dBm	
Gain	20 dB	

Fig. 1

5 MHz IN

EXP. RCVR/ μWAVE LINK (2.5 MHz IF) IN

DSIF RCVR 3 (10 MHz IF) IN

RELAY BOX CHANNEL 1

RF IN

COMPLEX MIXER MODULE

REAL — LOW-PASS FILTER — AMPL. — REAL OUT

IMAG. — LOW-PASS FILTER — AMPL. — IMAG. OUT

DSIF RCVR 4 (10 MHz IF) IN

RELAY BOX CHANNEL 2

RF IN

COMPLEX MIXER MODULE

5 MHz IN

REAL — LOW-PASS FILTER — AMPL. — REAL OUT

IMAG. — LOW-PASS FILTER — AMPL. — IMAG. OUT

KROHN-HITE FILTERS 48 dB/oct

DYNAMICS AMPL.

ANALOG OUTPUTS TO MULTIPLEXER INPUTS

Fig. 1. Complex mixer system block diagram

Fig. 2

RF INPUT

BUFFER AMPL. G = -14 dB

LOW-NOISE AMPL. G = 40 dB

$$\frac{-2\omega_c^2}{s^2 + \sqrt{2}\omega_0 s + \omega_c^2}$$

ACTIVE LP FILTER $f_c = 1$ MHz

UNITY-GAIN BUFFER AMPL.

REAL OUTPUT

BUFFER AMPL. G = -14 dB

LOW-NOISE AMPL. G = 40 dB

$$\frac{-2\omega_c^2}{s^2 + \sqrt{2}\omega_0 s + \omega_c^2}$$

ACTIVE LP FILTER $f_c = 1$ MHz

UNITY-GAIN BUFFER AMPL.

IMAGINARY OUTPUT

f_{CL} (40/10 MHz)

2-FF GRAY CODE COUNTER (TTL)

$f_0 = \frac{f_{CL}}{4}$ — TTL DRIVER — SIN $\omega_0 t$

$f_0 = \frac{f_{CL}}{4}$ — TTL DRIVER — COS $\omega_0 t$
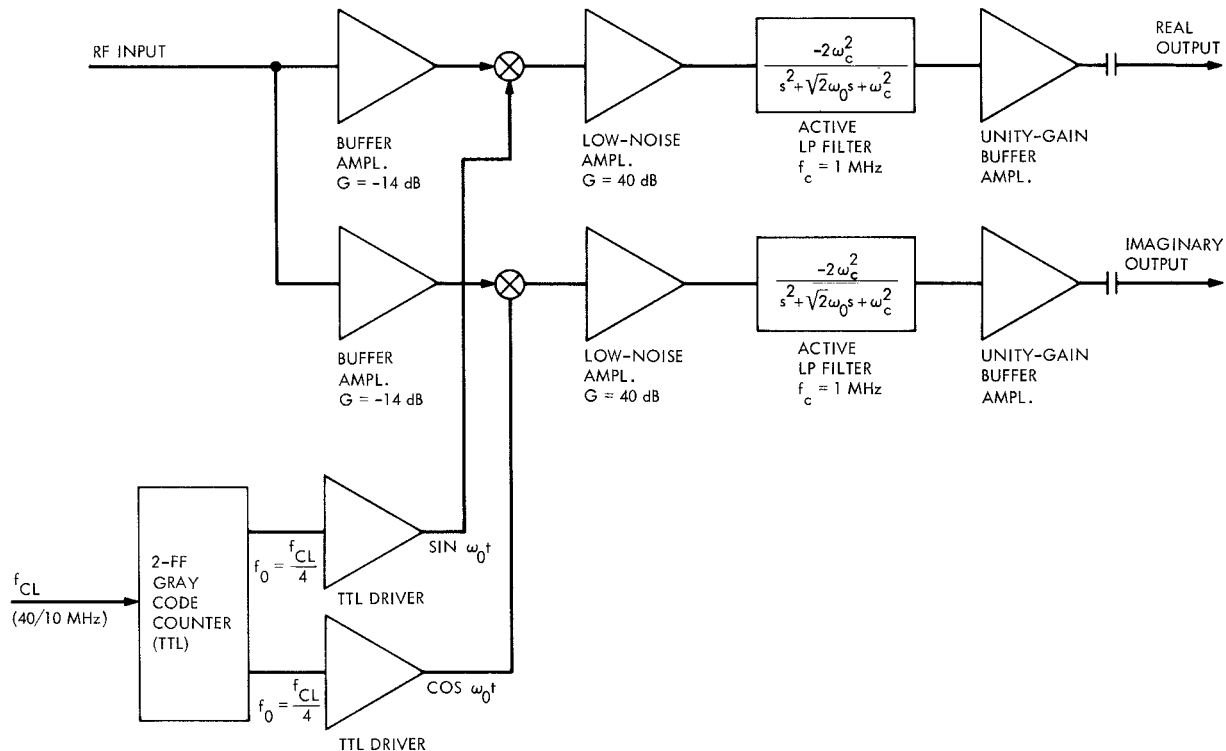
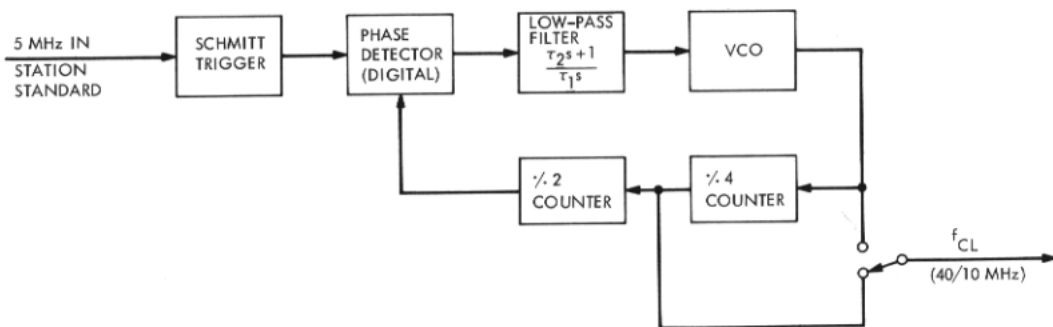**Fig. 2. Complex mixer module block diagram**

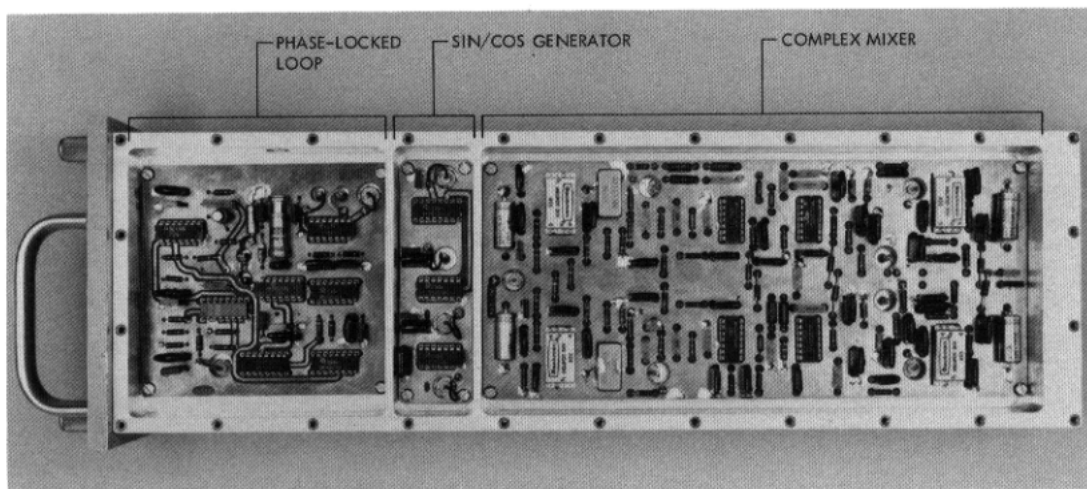Fig. 3. Phase-locked-loop block diagram

Fig. 4. Complex mixer RF standard DSN module

Fig. 5. Complex mixer front panel