A BIPOLAR OSCILLATOR FOR THE 6 GHZ COMMUNICATIONS BAND

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A Si bipolar transistor, cavity stablized, oscillator is described that exhibits phase noise that is greater than 83dB below a reference 100KHz tone 300KHz from the carrier in a 3.1KHz bandwidth, less than 2 watts power consumption at 25°C, a typical frequency stability of ±0.00035% over the -20 to 70°C, and utilizing packaged devices.

A Si bipolar, cavity stabilized, transistor oscillator has been developed that will cover the 5.9 to 6.4 GHz communications band. Besides full band coverage the unit exhibits low power consumption, low phase noise, construction with packaged devices, low cost, ±.0005% stability and a signal free from spurious tones. The oscillator stability of ±.0005% over -20 to 70°C range is obtained with an AFC circuit. The cavity is electronically tuned by a Si hyperabrupt diode for both the AFC varactor and an additional modulation varactor which may be added. This paper will concentrate on the design of the 6 GHz bipolar oscillator and the results that were obtained.

The oscillator is intended to be used as either (or both) the transmit or receive local oscillator in a 2700 channel heterodyne radio (MAR-6C) covering the 5.9-6.4 GHz domestic communications band. The specific design specifications were: 1) FM noise -83dB below a reference test tone deviation of 100 KHz, when measured in 3.1 KHz bandwidth, 300 KHz from the carrier, (figure 1), 2) frequency stability of ±0.0005% over a range of -20 to +70°C, 3) low cost, 4) all tones to be at least 80dB below the 100KHz test tone level, 5) 6 Watts of DC power consumption.

Oscillator Design:

In the design phase, many different configurations for the oscillator were considered. The final decision was to use a fundamental Si bipolar transistor oscillator. This choice was based on the following information about a fundamental transistor oscillator: 1) known low noise characteristics, 2) low DC power consumption, 3) reproducibility, and 4) simplicity of design. For similiar reasons the Si bipolar transistor was chosen as the active device.

The design of the oscillator is based on maximizing the negative resistance as seen looking into the base of the transistor by putting the appropriate reactance in the emitter. The results of varying the reactance in the emitter is shown in figure 2. As can be seen from this figure, the maximum negative resistance occurs with an inductive load of approximately 300 ohms. As the frequency is increased, the reactive load which produces the maximum signal increases. Therefore an inductor with a large reactance is placed in the emitter. With this reactance in the emitter of the transistor, the base of the transistor is then coupled to a TM010 cavity. The transistor is lightly coupled to the cavity in order to keep the loaded Q of the cavity high. The transistor is a packaged device with the collector lead of the package soldered to the cavity in order to insure a good thermal and electrical contact.

AFC Board:

In order to meet the stability requirements, an automatic frequency control (AFC) circuit is used to keep the 6 GHz ocscillator on the required frequency. A block diagram of the AFC/oscillator is shown in figure 3. A varactor is coupled into the cavity for the AFC circuitry. The coupling is just tight enough to provide the necessary correction frequency to the cavity to keep the oscillator within the frequency stability requirements. The AFC board material is epoxy filled fiberglass (commonly referred to as G-10).

Experimental Results:

Table I presents the experimental results that were obtained with this design. The final unit covers the frequency range of 5.970 to 6.360 GHz with a minimum power output of +14dBm. Typical stability when locked to the crystal is ±0.00035%, although when the unit is unlocked the stability of the oscillator is -0.2 MHz/°C. The oscillator draws 0.27 watts of power while the completed assembly draws 1.8 watts at 25 C. Figure 1, shows a typical curve of the FM noise. No spurious tones were observed when the down converted signal was swept with a selective voltmeter.

Conclusion:

In conclusion, a source for the 5.9 to 6.4 GHz communications band consisting of a fundamental Si bipolar transistor oscillator and an AFC board constructed on a fiberglass-epoxy board has been described. The source exhibits phase noise that is greater than 83dB below a reference 100KHz tone 300KHz from the carrier in a 3.1KHz bandwidth, less than 2 watts power consumption at 25°C, and a typical frequency stability of ±0.00035% over the -20 to 70°C.

References:

1) E. C. Niehenke and R. D. Hess, "A Microstrip Low-Noise X-band Voltage-Controlled Oscillator," IEEE Trans. Microwave Theory Tech., vol. MTT-27, pp. 1075-1079.

2) Y. Wu, H. Yaun, and J. B. Kruger, "X-band varactor-tuned bipolar transistor oscillator," ISSCC 1978, pp. 162-163.

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Table 1
Experimental Results

Freq. range	5.970-6.360 GHz
Output power	+14dBm
Stability:	
Locked to Crystal	± 0.00035%
Free running	-0.2 MHz/°C
Power consumption	
Oscillator	0.27 Watts
Source	1.8 Watts
Temperature range	-20 to 70°C

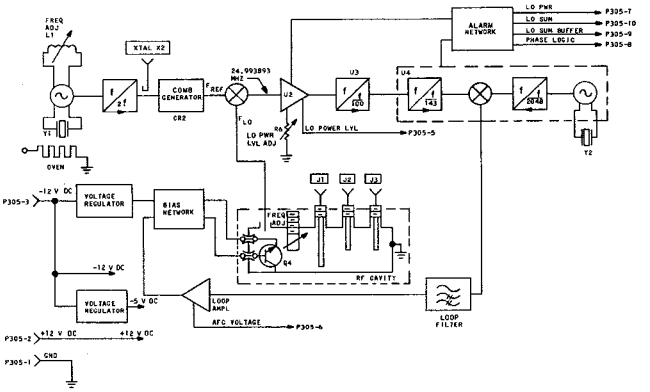

FIGURE 3 – BLOCK DIAGRAM

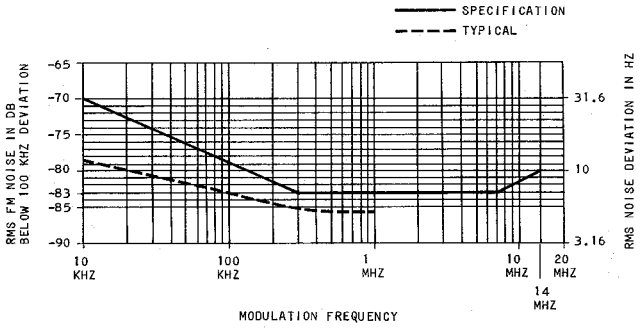

FIGURE 1 – FM NOISE

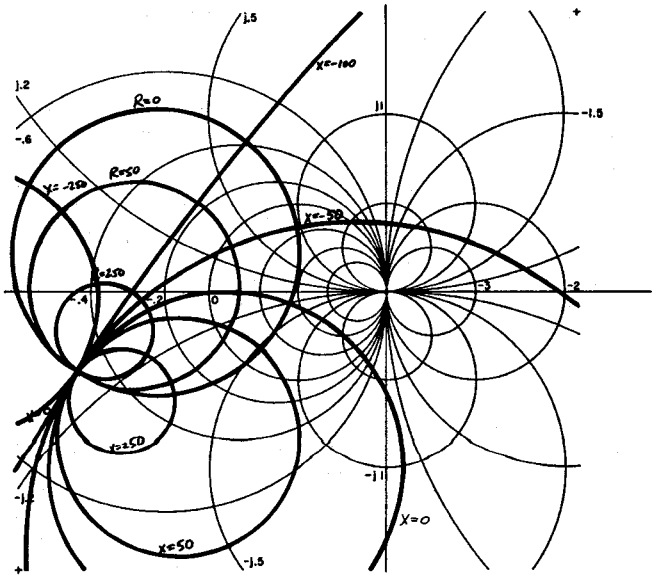

FIGURE 2 – EFFECT OF EMITTER LOAD ON BASE INPUT CIRCUIT

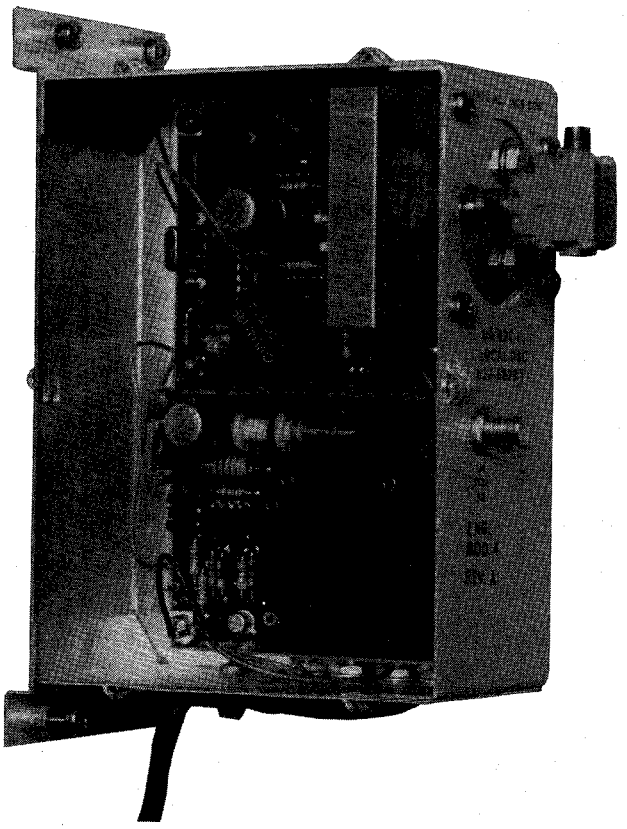

FIGURE 4 – FINAL OSCILLATOR ASSEMBLY