A NEW S-BAND FM TELEMETRY TRANSMITTER

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ABSTRACT

This paper describes the design, test and the analysis of the test results of a new type S-band FM telemetry transmitter.

Compared with the modulator adopting conventional fundamental crystal direct modulation, the transmitter which adopts UHF fundamental crystal direct modulation has a comparatively better modulation characteristics and a higher center frequency stability. The test results show that the deviation sensitivity of the transmitter is up to 400KHz/Vrms, frequency response is DC~200 KHz, total harmonic distortion is 3% and the center frequency stability is ten to the minus fifth power within the range of -30~+70°c. Because of the high operating frequency of the modulator, the complicacy of the frequency multiplier has been requced, design of circuitry simplified and harmonic and spurious outputs has been improved to a great extent.

Key words: telemetry transmitter, direct modulation, UHF fundamental crystal.

INTRODUCTION

The problem which is mostly concerned by the FM transmitter designers is how to ingeniously solve the contradiction between modulation characteristics and center frequency stability so as to satisfy the harsh requirements of transmitter electronic perfermences and geometric dimensions demanded by engineering applications. The requirement on transmitter modulation characteristics differs greatly from different applications. Generally speaking, for telemetry system having larger data capacity, for instance, missile, space shuttle etc., their transmitters are required to have higher frequency responce and greater deviation capability, while for data transmission systems in tactical rockets, satellites as well as nonmilitary telemetry applications, the requirements on transmitter frequency response and deviation capability are relatively lower. For large capacity data transmission, the transmitters are prone to be designed by using an IF modulator with good modulation characteristics and a high reliability local oscillator to obtain an ideal stable frequency-modulated output or by using the method of phase lock to achieve the stable frequency-modulated output after conversion division of the frequency modulator operating on output frequency. Yet the composition of circuitry using the above-mentioned methods are too complicated and bulky and expensive, hence not suitable for some applications that requires less data capacity but harsh requirements on bulk. So we have made a new approach to the design methods for frequency-modulated transmitters, that is UHF fundamental crystal direct modulation. It has been proved that this kind of design obtains both ideal modulation characteristics and good center frequency stability. Compared with the methods of frequency-conversion and phase lock, it has the advantages of simple circuitry, more efficient, small bulk and of low cost; and compared with the methods of using traditional VHF fundamental crystal direct frequency modulation, it has the merits of better modulation characteristics, less frequency multiplication and of higher harmonic and spurious outputs.

COMPOSITION OF TRANSMITTER AND SCHEMATICS OF FUNDAMENTAL CIRCUITRY

The composition of transmitter is shown in figure 1. It consists of a frequency modulator, a buffer amplifier, a frequency multiplier, a band-pass filter and a power amplifier.

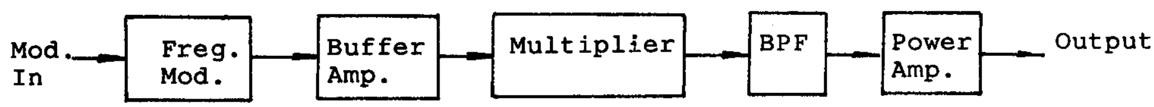

Figure 1. Block Diagram of a Transmitter

The frequency modulator operates on 400MHz band and its operating frequency can be raised to S-band for output after frequency multiplification.

The schematic of frequency modulator is shown in figure 2, in which W represents crystal frequency modulation networks and also shown in figure 2 is the Colpitts Oscillator Circuitry. In order for the circuitry to oscillate steadily, the W networks must appear in inductive features.

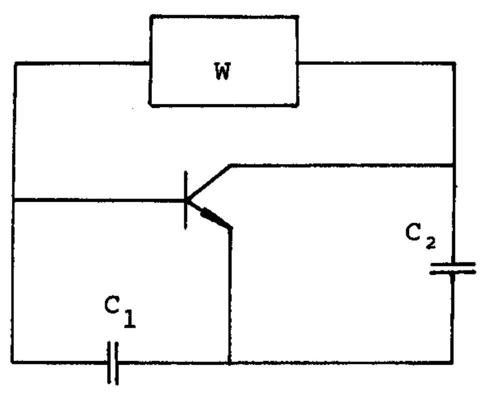

Figure 2. Principle Circuit of the Modulator

Crystals manufactured by traditional grinding technique has a very difficult problem, that is its fundamental resonance frequency is difficult to be raised to a certain extent, usually less than 30MHz because of the limitation of its thickness. The UHF crystal used by the new S-band frequency-modulated telemetry transmitter is manufactures by the method of plasma photoetching. The crystal chips of the resonator are selected from the first class artificial crystals, the diameter of each chip is 7mm, thickness 55.4,µm (identical to 30MHz fundamental frequency), AT cutting, double face mechanical polishing. The diameter of the photoetched area by ion beam is only a few µm and the size of crystal chip electrode is 50 by 50 (µm). The electrode which is 1000A thick has been accomplished by vacuum evaporating aluminium-plating. Packaged in a small metal case, the electrodes are vertically intersected and the coincident part of the two electrodes forms a squre, which is shown in figure 3.

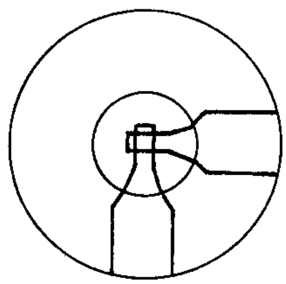

Figure 3. Schematic of the resonator

As a result of using the method of ion beam photoetching, the crystal chips can be processed as thin as a wafer, thus greatly increases the fundamental frequency of the crystals. Shown in figure 4 are the equivalent circuitry and reactance-frequency characteristics,

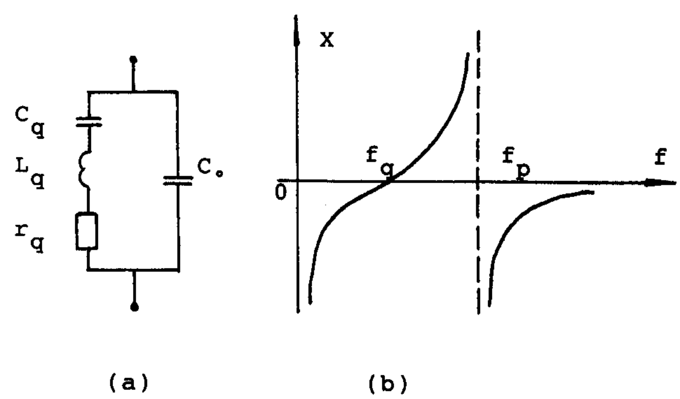

Figure 4. (a). Equivalent Circuitry of the Crystal
(b). Reactance Curves of the Crystal

of which the serial resonance frequency is:

$$f_q = 1/2\pi \sqrt{L_q C_q}$$

and the parallel resonance frequency is:

$$f_p = 1/2\pi \sqrt{L_q C_q C_o / c_q + C_o} = 1/2\pi \sqrt{L_q C_q / 1 + C_q / C_o}$$

We know from figure 3(b) that when the operating frequency of the crystal is between f_q and f_p , its characteristic impedance must appear inductive and the crystal is equivalent to a high Q inductor working in the tuned loop. In this case, the circuit shown in figure 2 can work stably, that is to say, if you want to realize crystal direct frequency modulation, the transient frequency must vary between f_q and f_p, or put it another way that the maximum frequency deviation can't exceeds half of this frequency range. The interval of crystal serial and parallel resonance frequency is relatively small, usually between 10^{-3}~10^{-4} of order. Whereas for UHF fundamental crystal, due to its high operating frequency, the static capacitance C_o is less than 0.3PF, therefore a satisfactory wider $|F_q-f_p|$ value, usually up to 400KHz can be achieved. This is what the designers are interested in, for it means that the bigger the value is, the greater the frequency deviation can be gained.

In the design of frequency-modulated networks, the variable-capacitance diode and the crystal is in serial configuration, so as to reduce the influence resulting from the unstability of the variable-capacitance diode. When junction capacitance of the variable-capacitance diode varies with the modulating signals, the equivalent impedance of the crystal also varies, causing the frequency of the crystal oscillator to be modulated. The static capacitance of the variable-capacitance diode in series collection with the crystal oscillator will make f_q near f_p, thus reducing the modulation capavility. AN inductor is introduced serially into the variable-capacitance diode circuit to offset influence from the static capacitance. Two variable-capacitance diodes are used as a modulator to increase modulation sensitivity and improve modulation characteristics. In addition, a temperature compensation network is added to the input circuit of the modulating signal to improve the stability of frequency deviation within wider temperature range.

TEST RESULTS

The modulation characteristics and center frequency stability have been tested on a prototype, the results of which are listed below:

1. Shown in figure 1 are the modulation characteristics (the modulating signal input amplitude is 2Vrms)

modulation frequency (KHz)	DC	0.03	1	10	50	200
frequency deviation (KHz)	810	839	845	845	837	800
total harmonic distortion (%)		3.3	2.8	2.8	2.7	

Table 1. Modulation Characteristics

As will be readily seen from Table 1 that the modulation sensitivity is about 400KHz/Vrms.

2. Frequency-Temperature Characteristics within the Temperature Range of -30~+70°c are shown in Figure 5.

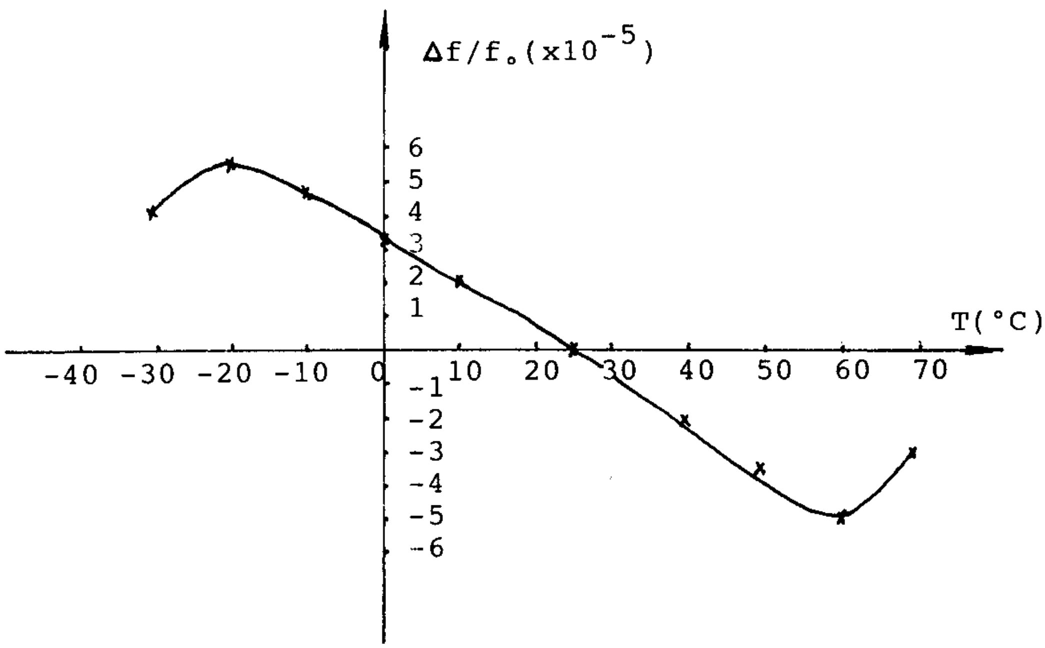

Figure 5. Transmitter Frequency-Temperature Characteristics

CONCLUSION

The statements mentioned above are the preliminary studies we have done on UHF fundamental crystal direct frequency modulation. As may be seen from the test results, the transmitter modulation sensitivity is 400KHz/Vrms, maximum frequency deviation may be up to 800KHz, frequency response is DC~200KHz, distortion is about 3% and the frequency sensitivity is ten to the minus fifth power. So we can say that, compared with the methods of frequency conversion, pfase lock and traditional VHF fundamental crystal direct frequency modulation, this new approach to frequency modulation is more practical for the applications of small capacity, low data rate vehicles, satellites and nonmilitary systems. No doubt, it will be used far and wide for many purposes, if the frequency response and center frequency stability are further improved. This problem remqins to be solved by future studies.

For the time being, the technique of surface acoustic wave modulation has arosed broad interest. It possesses the advantages of high oscillation frequency, miniaturization and its modulation characteristics is better than crystal modulation. But the frequency-temperature characteristics of the surface acoustic wave modulated oscillator is not as good as the crystals, usually ten to the minus fourth power. So during the phase of designing, an alternative can be made according to different requirements for different applications.

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