A Microwave Frequency Generation Unit for Space Applications

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Abstract - **Spacecraft systems designed to provide communications require the necessity to generate multiple, redundant local oscillator frequencies for various up/down converters in the payload. The design requirements are low noise, low power, small size and mass. They are also required to be SEU hard and total dose tolerant and reliable. The reliability is increased by having a design with built in redundancy. The FGU is powered from the spacecraft bus with dedicated EPCs, which are redundant. The FGU is phase locked to a stable reference, which is also redundant. Several test points in the form of telemetry are provided for checking unit functionality and operational characteristics**

I. INTRODUCTION

Spacecraft systems designed to provide mobile communications systems require the necessity to generate several local oscillator frequencies for various up/down converters in the payload [1]. The conventional technique of frequency multiplying a highly stable fixed reference signal is not recommended for spacecraft's having several local oscillator frequencies. The requirement of lower spacecraft mass, size and DC power can be accomplished by digital frequency synthesis using phase-locked loops [2]. An integrated circuit frequency synthesizer makes the system design easier and robust for space applications [3,4].

Figure 1 shows the overall configuration of a typical Frequency Generator Unit (FGU) designed for space applications. The FGU is configured in a modular, building block approach to meet the performance requirements and, in addition, allow for maximum flexibility throughout the development cycle. For ease of routing different frequencies to various up and down converters, the frequency generator is packaged into several assemblies as follows:

- Fixed Frequency Assembly (FFA)
- Output Distribution Network
- Reference Oscillator Assembly (RO1/2/3)
- Electronic Power Converter (EPC 1/2/3).

The three stable reference sources distribute a reference signal to N synthesizers in the payload using a passive distribution circuit. This 3 X N circuit is a passive network designed to have no single point failures. Most spacecraft frequency sources have multiple frequencies and each frequency is generated with three for one redundancy as shown. The frequency outputs are later combined with a passive combining network to provide the final outputs.

Figure 2 is a detailed functional block diagram of the FGU that has been developed. All fixed frequencies are generated in the FFA. The FFA contains its dedicated control card, 15 identical loops and the associated frequency converters packaged into one assembly. The frequency divider assembly is a means of chanellizing frequencies for the payload converters. The Reference Oscillator assembly consists of three 10 MHz high stable oscillators packaged into one unit.

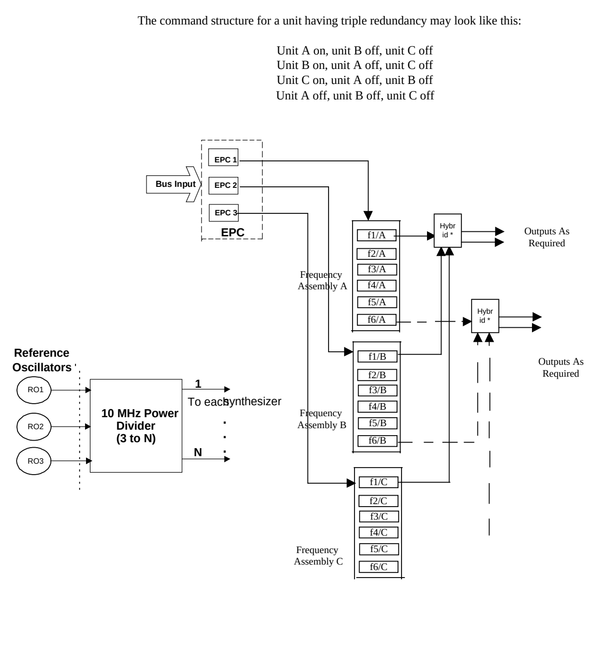

Figure 1 Frequency Generator Configuration

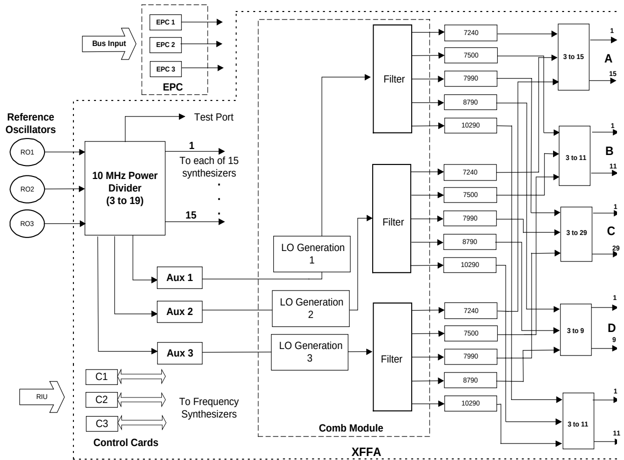

Figure 2. Frequency Generator Block Diagram

II. Frequency Synthesis

The FFA frequencies are synthesized from a stable 10 MHz reference source employing a phase-locked loops (PLL) design topology. All PLLs are similar in design and operate in the UHF band to minimize loop multiplication and therefore phase noise. The final output frequencies are obtained by frequency conversion as shown. The frequency is changed by setting the frequency control word [5] associated with the synthesizer. Figure 3 shows the synthesis approach for one of the frequency synthesizer modules. In this design example, fifteen such modules provide five distinct local oscillators with three for one redundancy. The DC voltage to each synthesizer module is routed directly from the associated EPC. In some applications DC power is routed to each synthesizer using commandable latching relays. The noise and ripple generated in the power supplies are attenuated by at least 80 dB by using a dedicated low noise regulation circuit for each synthesizer module. The high frequency interfering signals are attenuated by proper layout and by using RF feedthrus and LC filters

III. FIXED FREQUENCY ASSEMBLY

The Fixed Frequency Assembly (FFA) synthesizes the following frequencies:

1 7240 MHz
2 7500 MHz
3 7990 MHz
4 8790 MHz
5 10290 MHz

The FFA consists of 10 MHz reference signal amplification and distribution circuitry and all fixed frequency modules. This assembly generates 5 different frequencies with 3 for 1 redundancy resulting in 15 frequency modules. It also contains 3 Auxiliary signal modules. Each module is individually plugged into a chassis mounted backplane. The FFA also houses three Control Card Modules, which plug into the backplane assembly via Sub-D connectors and provide the necessary commands for the synthesizers.

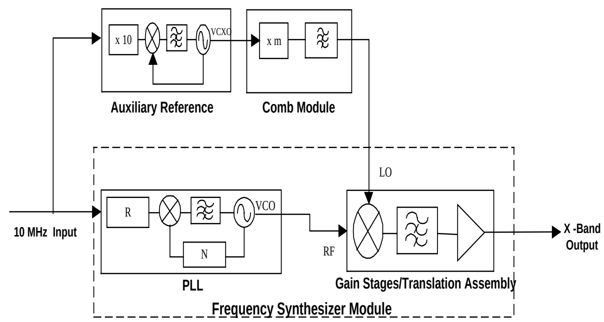

Figure 3. Frequency Synthesis Approach

IV. OUTPUT DISTRIBUTION UNIT

The output distribution unit (ODU) is a passive network and accepts 3 inputs from each of the frequency modules in the FFA and provides 16 outputs at each frequency.

V. MECHANICAL PACKAGING

Figure 4 shows the mechanical packaging design of the FGU. The design is completely modular and has a unique backplane assembly. The backplane assembly forms the base to which the other modules are bolted to and feeds power and commands to each of the plug-in modules. The DC interconnects between the modules and the backplane unit is made using “sub-D” connectors. The 3 X N power divider modules are mounted on top of the unit and are interconnected to the frequency modules with flexible coaxial cables with SMA connectors

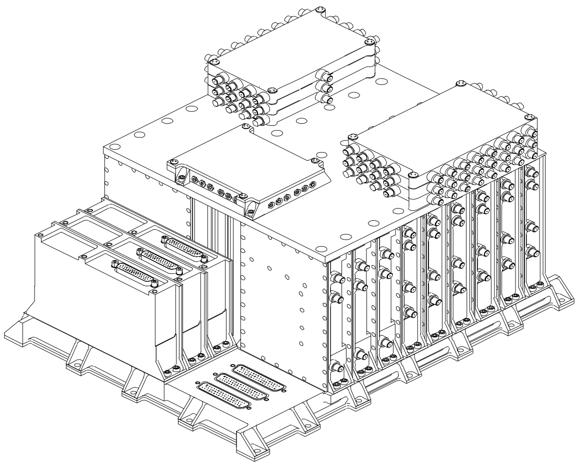

Figure 4. Frequency Generator packaging approach

VI. REFERENCE OSCILLATOR

The reference oscillator assembly consists of three 10 MHz highly stable oscillators. The stability requirement is ± 1 part in 10^8 with a stability better than ±3 parts in 10^{10} per day. Each oscillator employs a SC cut crystal for optimum phase noise performance. The crystal is mounted in an oven and temperature maintained to within ±1°C to obtain the required frequency stability.

VII. TEST RESULTS

The phase noise and spurious test data are shown in Figures 5 and 6.

VIII. CONCLUSION

The Frequency Generation Unit (FGU) shows the generation and distribution of redundant multiple output microwave frequencies for spacecraft applications. The FGU is configured in a modular building block approach to allow for maximum flexibility throughout the development cycle.

Figure 5. Phase Noise Performance Data at 8790 MHz

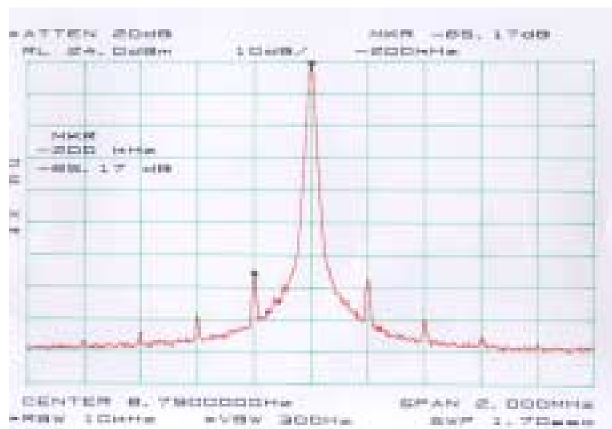

Figure 6. Spurious Test performance at 8790 MHz

IX. ACKNOWLEDGEMENTS

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