Multi-functions Integration and Intermodulation Interference of TT&C system

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ABSTRACT

This paper describes technical problems in system integration, Intermodulatin interference, digitalization, obital accuracy, low-noise design of the new generation TT&C system as well as their solutions.

INTRODUCTION

The new generation TT&C system features is multi-function, multi-subcarrier, multi-carrier, high accuracy, high data rate. It applies united S-band system up to the CCSDS, which brings some new technical problems to the system designers, such as:

MULTI-FUNCTIONS INTEGRATION

System integration is one of the trends of electronic systems, with which the reliability, maintenability and expandability of the system can be improved with low cost, weight and small volume.The new generation TT&C system is required to offer multi-functions, such as orbit determination, telemetry, telecommand, data transmission etc. The main technical problems and their solutions are described as below:

l) Signal design

The multiplex signal design can be applied in either “frequency-division system” or “time-division system”. According to the actural circumstances, both of them have been used in the system, which includes: multi-TT&C subcarriers and carriers in frequency-division system, and DDT in time-division system.

2) Equipment reusing and sharing

Reuse the equipments operating simultaneously and share the equipments operating in different time period, which could simplify the system design, improve the system reliability and reduce the cost.

3) Computer applification for system reconfiguration, built-in-test (BIT), error isolating and backup equipment switching

The central computer of the monitoring console as well as the PCs and MCPs of the individual subsystems are interfaced with SIO (RS-422 asynchronous bus) via Ethernet to perform data interchange and control, which in turn to realize the equipment reconfiguration, parameters setting and information synthesis.

4) Modularization and Multi-purpose design

The multi-function module is applied for flexible and convenient system reconfiguration, which further improved the system integration level.

INTERMODULATION INTERFERENCE OF MULTI-SUBCARRIER MODULATION

Because it is a PM system of multi-subcarrier midulation, it will generate Intermodulation interference of multi-subcarrier modulation.

The resuets of analysis and experimenfs in This paper show, That as long as transmission system' s amplitude-frequeney characterica even symmetry, phase-frequeney characteristics odd symmetry, phase orthogonality of PM Demodulation and reducing non-liearity of modem are strictly controlled, high-order inretference and combination interfence of subcarrier may be supressed. At the same time, delay reliability of ranging tone may be increased amd therefore accuracy of distance measurement further can be increased.

Author Derives formulas of intermodulation interfrence and phase of ranging tone. For sideband of carrier in-phase:

$$\Phi_{1\Omega}=tg^{-1}\frac{H_{-1}\sin[(\Phi_o-\Phi_{-1})+\Delta\Phi]+H_{+1}\sin[(\Phi_{+1}-\Phi_o)-\Delta\Phi]}{H_{-1}\cos[(\Phi_o-\Phi_{-1})+\Delta\Phi]+H_{+1}\cos[(\Phi_{+1}-\Phi_o)-\Delta\Phi]} \tag{1}$$

$$\Phi_n=tg^{-1}\frac{H_{-n}\sin[(\Phi_o-\Phi_{-n})+\Delta\Phi+\pi]+H_{+n}\sin[(\Phi_{+n}-\Phi_o)-\Delta\Phi]}{H_{-n}\cos[(\Phi_o-\Phi_{-n})+\Delta\Phi+\pi]+H_{+n}\cos[(\Phi_{+n}-\Phi_o)-\Delta\Phi]} \tag{2}$$

$$B_{1\Omega}=\frac{J_1(m)}{2}\{H_{+1}^2+H_{-1}^2+2H_{+1}H_{-1}\cos[(\Phi_o-\Phi_{-1})-(\Phi_{+1}-\Phi_o)+2\Delta\Phi]\}^{1/2} \tag{3}$$

$$B_n=\frac{A_n}{2}\{H_{+n}^2+H_{-n}^2-2H_{+n}H_{-n}\cos[(\Phi_o-\Phi_{-n})-(\Phi_{+n}-\Phi_o)+2\Delta\Phi]\}^{1/2} \tag{4}$$

For sideband spectrum of carrier out-phase

$$\Phi_n=tg^{-1}\frac{H_{-n}\sin[(\Phi_o-\Phi_{-n})+\Delta\Phi]+H_{+n}\sin[(\Phi_{+n}-\Phi_o)-\Delta\Phi]}{H_{-n}\cos[(\Phi_o-\Phi_{-n})+\Delta\Phi]+H_{+n}\cos[(\Phi_{+n}-\Phi_o)-\Delta\Phi]} \tag{5}$$

$$B_n=\frac{A_n}{2}\{H_{+n}^2+H_{-n}^2+2H_{+n}H_{-n}\cos[(\Phi_o-\Phi_{-n})-(\Phi_{+n}-\Phi_o)+2\Delta\Phi]\}^{1/2} \tag{6}$$

Where:

$\Phi_{1\Omega}$ — Phase of ranging tones
$B_{1\Omega}$ — Amplitude of ranging tones
Φ_n — Phase of intermodulation interference
B_n — Amplitude of intermodulation interference
$\Delta\Phi$ — Phase orthogonality of PM Demodulation

It can be seen from formula(6):

When $H_{+n} = H_{-n}$, $\Phi_{+n} = \Phi_{-n}$, $\Delta\Phi$, then $B_n = 0$
Thus intermodulation interfrence of subcarrier may be supressed.

It can be seen from formula(1):
The nonstabilities of H_{+1}, H_{-1}, Φ_{+1}, $\Delta\Phi$, will reduce the accuracies of $\Phi_{1\Omega}$ and ranging measurement.

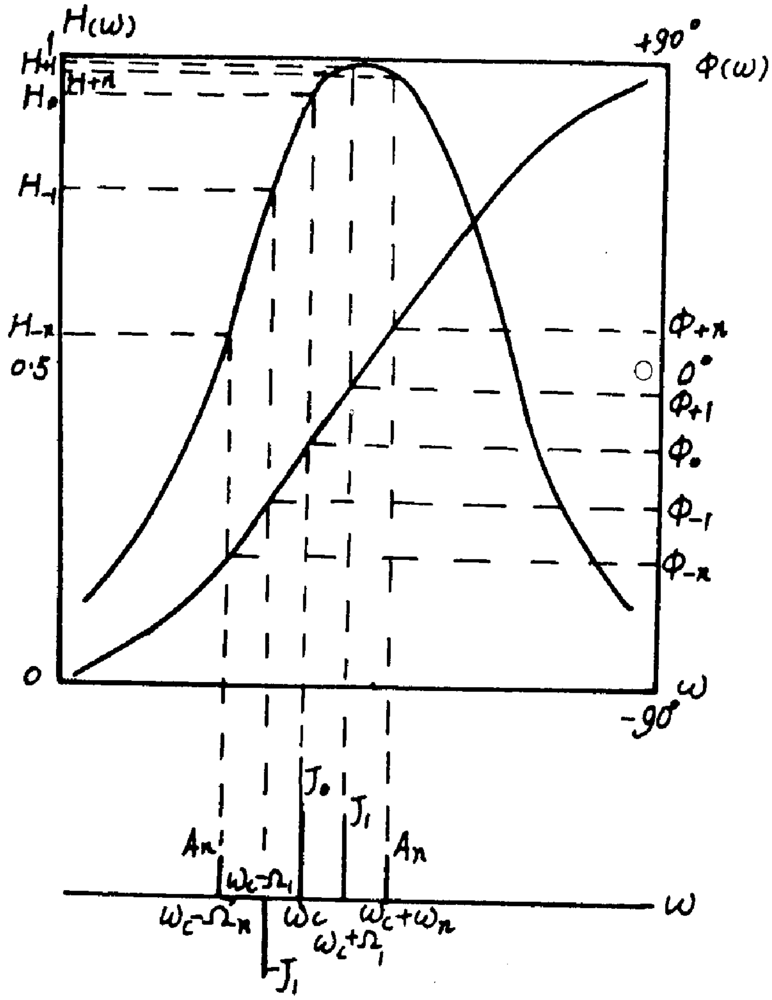

Fig 1 Amplitude-frequency, phase-frequency characteristics and signal spectrum

DIGITALIZATION

The advantages of system digitalization are described as below:

- To increase accuracy of orbit determination
- To improve stability, reliability and maintenability of equipments
- To be useful for system integration, computerization and programmablization
- Easy function expansion and modularization
- To make full use of software resources
- With standard interfaces easy to be exchanged, etc.

The main solutions is shown as follows:

1) Terminal full-digitalization, including programmablility for terminals in range and range rate measuring as well as telemetry and telecommand.

2) Receiver digitalization, such as the digital PLL, digital range rate measurement and fast Fourier Transform (DPLL/DRR/FFT), which is called the “3 in 1" digital carrier loop.

3) Monitor & Control subsystem's computerization and networking.

ORBIT DETERMINATION ACCURACY IMPROVEMENT

1. The angle accuracy can be improved by using double-channel monopulse system, vestigial-carrier Doppler track filtering, self-adaptive composite controlling, sum/differencial phase self-calibration.
2. The range accuracy can be improved by applying full digital programmable ranging, digital filtering, and controlling the target of channel group delay and AGC, as well as major side-tone digital loop.
3. The accuracy of range rate is improved by using digital carrier loop to get the loop control code of DCO and acquire the real-time range rate message through digital processing such as smooth filtering.

LOW-NOISE DESIGN

The system design is based on low-noise design according to the maximum value of G/T, not either of the value of G or T.

Since the noise temperature of LNA is quite low, the system noise temperature is decided mainly by the noise temperature of the antenna and feeder line, so the low-noise design of antenna feeder system becomes important. The following methods can be adopted:

- Low-noise antenna design: the antenna edge illumination level is designed to make the value of G/(Tr+Tl+Ta) maximum (Tr, Tl and Ta represent the noise temperature of receiver, feeder loss and antenna respectively) when the value of Tr+Tl is certain, while in the mean time decrease the break of antenna pedestal and minor face and reduce the antenna sidelobes.
- The LNA with transmitting signal attenuation filter is used to reduce the requirements to filter rejection band and decrease the insertion loss.
- The noise temperature of LNA is reduced further by cooling.

SUMMARY

The above content reviews the main technical problems of the new generation TT&C system. Other problems are not described here.