STEADY-STATE, QUASI-STEADY-STATE AND TRANSIENT-STATE ANALYSES OF DELAY LINE DISCRIMINATORS FOR FM NOISE MEASUREMENT

Jin-ping Ruan

Communication, Telementering and Telecontrol Research Institute of Ministry of Electronics, Shijiazhuang, China

ABSTRACT

The steady-state, quasi-steady-state and transient-state concepts are introduced to the analyses of delay line discriminators for FM noise measurement. Only by this means, is it possible to determine the admitted range for RF drift when the discriminator has been adjusted to the nominal frequency; the linearized frequency deviation range when it's used as large frequency deviation measurement, f.e. the system caliblation and the measured range of the baseband frequency respectively, so that the system constrained performances can be mastered to the full.

INTRODUCTION

Though many reference papers have analysed the delay line discriminators for FM noise measurements, different papers used different methods and they can't discribe its operation, especially the system constrained performances, more integral and clear. But when the system is used to measure the FM noise, it's more important to understand these performences for fear of making some mistakes. In this paper, the concepts about steady-state, quasi-steady-state and transient-state analyses are introduced, therefore all these are mastered as a integral.

It's natural that this method can be used successfully to analyse not only this sort of discriminators but also other relative systems.

GENERAL ANALYSES

There are many projects about the delay line discriminators for FM noise measurement. Simplifying the discussion and aiming at our subject, we select the basic project, Fig.1, as the analysing model. All the other projects can be handled by the similar method. In practical, for Fig.1 it also can be divited into two used conditions: one is Usm=Urm=Uom (when the signal is larger); the other Usm$\ll$Urm (when the signal smaller). For the same reason, we'll only discuss the former.

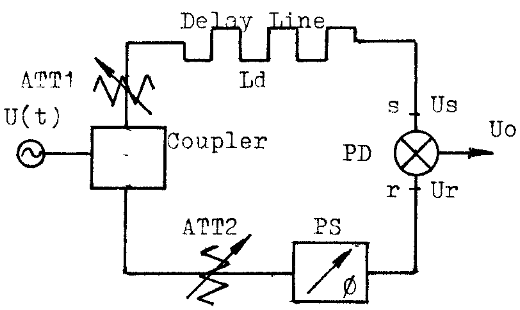

Fig.1 Analysing Model

In general, the balanced mixer is used as phase detector (PD). It belongs to the balanced addition type. Let the signals at its ports of s and r as follows:

$$(1)\quad \begin{cases} Us=Usm\ \sin[2\pi\nu o(t-\tau)+\phi(t-\tau)] \\ Ur=Urm\ \sin[2\pi\nu ot+\phi(t)+\phi] \end{cases}$$

Adjust the phase shifter (PS), and let it satisfy the condition of phase quadreture. We can get the discriminator output.

$$(2)\quad Uo=2\sqrt{2}Kd\ Uom\ \sin[\phi e(t)/2]$$

where: νo= nominal frequency;
$\phi(t)$= variable phase with t;
ϕ = fixed phase after PS is adjusted;
Kd= detect efficiency of the diodes in PD;
τ = delay time (=Ld/Vd, Ld length of the delay line; Vd phase velocity);
$\phi e(t)=\phi(t)-\phi(t-\tau)$.

NEW ANALYTIC CONCEPTS

Steady-state Analysis

Use -- to determine the admitted range for RF drift after a discriminator is adjusted to the nominal frequency.
Condition -- the nominal frequency drift slowly from νo to $\nu o+\Delta\nu$.
In this case: $\phi(t)=2\pi\Delta\nu t$; $\phi e(t)=2\pi\Delta\nu\tau$.

By analysing, we can get the steady-state characteristic equation (3), its characteristic curve, Fig.2, and the system

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contrained performance about the admitted range for RF drift when the sensitivity is decreased less than 1dB, Eq.(4).
Steady-state characteristic equation:

(3) $U_o=2\sqrt{2}K_dU_{om}\sin(\pi\Delta\nu\tau)$

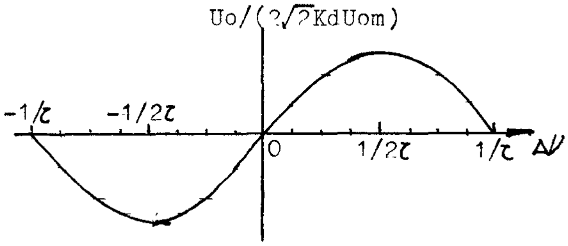

Fig.2 Steady-state Characteristic

The admitted range for RF drift:

(4) $\Delta\nu<0.144/\tau$

Quasi-steady-state Analysis

Use -- to determine the linearized frequency deviation (FD) range when the large FD signal is measured, f.e. the system calibration.
Condition -- the cycle of the modulating signal $1/f\gg\tau$.
In this case: $\phi(t)=2\pi[\Delta f\sin(2\pi ft)]t$
$\phi e(t)=2\pi\tau\Delta f\sin(2\pi ft)$
Here let the modulating component is $\Delta f\sin(2\pi ft)$ (Δf= peak frequency deviation).
By analysing, we can get the correct output equation satisfied quasi-steady-state condition, Eq.(5), its characteristic curve, Fig.3, and the system constrained performance about linearized FD range when it's used as large FD measurement and the linearized error is less than 1dB, Eq.(6).
Correct output equation:

(5) $U_o=4\sqrt{2}K_dU_{om}J_1(\pi\tau\Delta f)$

where: J_1= one order Bessel function.

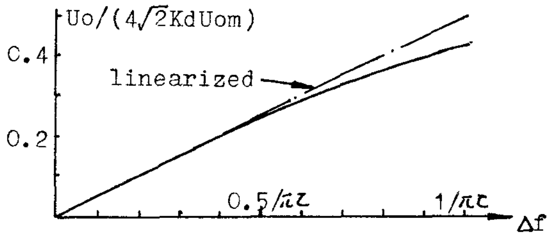

Fig.3 Quasi-steady-state Characteristic

The linearized FD range:

(6) $\Delta f<0.285/\tau$

Transient-state Analysis

Use -- to determine the measurement range of the baseband frequency (BF) for FM noise measurement.
Condition -- none.
In this case: $\phi(t)=(\Delta f/f)\cos(2\pi ft)$
$\phi e(t)=2(\Delta f/f)\sin(\pi ft)\sin[2\pi f(t-\tau/2)]$
Here still let the modulating component is $\Delta f\sin(2\pi ft)$, but for the noise it means to be its equivalent value.
By analysing, we can get the correct output equation (7), its characteristic is shown as the photograph, Fig.4, and the system constrained perfirmance about linearized BF range, Eq.(8).
Correct output equation:

(7) $U_o=2\sqrt{2}K_dU_{om}\pi\Delta f\sin(\pi f\tau)/(\pi f\tau)$

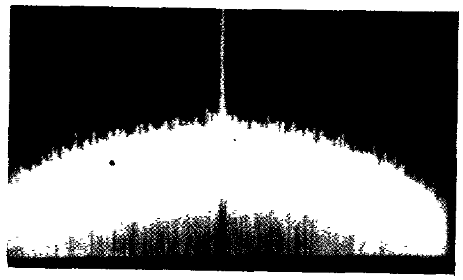

Fig.4 Transient-state Characteristic

The linearized BF range:

(8) $f<0.255/\tau$

All above analyses can make us derive the linearized output equation (9).

(9) $U_o=2\sqrt{2}K_dU_{om}\pi\tau/f$

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