USING MULTI-CARRIER PROBING SIGNALS FOR DETECTING NON-LINEAR OBJECTS

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ABSTRACT*: In this paper an experimental model of non-linear radiolocation channel and certain calibration methods are shown. An etalon type non-linear object has been used for the calibration of the experimental model.*

KEYWORDS*: model of non-linear radio location channel, calibration methods, non-linear object.*

1. INTRODUCTION

A major problem with non-linear radars (NLR) is their short range of operation. To increase the range of detection can be used multi-carrier signals [1,2] proposes a technical solution with dual-carrier signal.

Method for synthesis of optimal signal is still not developed. Also the advantage of dual-carrier signals compared to single-carrier signals is not applied yet.

2. SYNTHESIS OFPROBE SIGNALS FORMULTI-CARRIERNLR

The main property non-linear object is the capability of manipulation of signals with traditional frequency convertor. The only difference is the means of multiplexing of both signals. In the case of NLR the multiplexing is carried until the electromagnetic waves propagation medium, which allows the multiplexing of multiple signals with various amplitude, frequency and phase. Another important matters that no working algorithm for frequency conversion the probing signals has been developed yet. All that makes the multicarrier probing in NLR and the effectiveness analysis remain unresolved.

A system of deterministic signals has been considered. Base don’t he model of the non-linear radio channel, we can imagine NLR as a set of generator so f monochromatic signals. The probing signal is shown below

$$S_{PS}(t) = \sum_{j=1}^{N} A_j cos\omega_j t \quad (1)$$

Where Aj is the amplitude of the signal with frequency ωj and N is the number of monochromatic signals.

In particular for dual-carrier probing signal with spectral components frequencies$\omega_1$and$\omega_2$can be written:

$$S_{PS}(t) = \cos(\omega_1 t) + \cos(\omega_2 t) \quad (2)$$

For weak interaction when nonlinear transformation is determined by quadratic member of the decay of the order of Taylor, the dispersed signal by the object can be represented in the following form:

$$S_{DSPS}(t) = \beta\,(1 + \cos(\Omega t))\cos((\omega_1 + \omega_2)t) \qquad (3),$$

Where β is a constant coefficient, and$\Omega = \omega_1 - \omega_2$.

3. SINGLE-CARRIER AND MULTI-CARRIER IRRADIATION OF NONLINEAR OBJECTS

The intensity of the reflected signal $S_{DSPS}(t)$exceeds one and a half times the intensity of the reflected signal in single-carrier irradiation. In [2] has shown that for transformations of second order deviation of the power of the reflected signal from the average value increases proportionally with the increasing number of monochromatic signals N in the probing signal if the following condition:

$$\omega_i - \omega_{i+1} = \omega_{i+1} - \omega_{i+2} \qquad (4)$$

I.e. the rate of frequency change of the monochromatic waves is equal. In this case, the elements formation of the spectrum of reflected signal of second order involves more than two spectral components of the probing signal. In particular *N-1* non-linear components with frequencies

$$\omega_n = \omega_1 + \omega_N = \omega_2 + \omega_{N-1} = \omega_3 + \omega_{N-2} \qquad (5)$$

are summed coherently.

The equality of average powers of the probing signals can have different interpretations. In particular, if the dual-carrier signal is formed by using two antennas, to compare the energy of the reflected signals at single-carrier and multi-carrier irradiation it is necessary to modify one frequency in a direction or each the other($\omega_1 \rightarrow \omega_2$). In case of equality of the average power of the probing signal flux density in single-carrier irradiation will be greater than the flux density in dual-carrier. This is caused by the increase in the effective area of the antenna twice. For this reason to be correct comparison is important to keep the same area of the antenna system.

In [2] are compared the reflected signals from non-linear objects irradiated with single-carrier and dual-carrier signals using frequency modulated probing signals.

Using directional coupler and power divider one of the signals with average power irradiates through one of the antennas, and the other is delayed and irradiated through the other antenna. In the experiment are compared dual-carrier signal with two antennas and single-carrier signal with one antenna, which proves the significant increase of energy of the reflected signals with multi-carrier irradiation compared to single-carrier.

Multi-carrier irradiation has specific features that should be considered. The first one is the use of ultra wide band width receiver, which in turn leads to reduction of SNR.

Another feature is that the necessary linearity of power amplifiers in wide dynamic range of transmitter has to be provided. It also needs to ensure a uniform gain antenna in a sufficiently wide frequency range.

In [1] is developed on the case by the use of different probing signals from N generators with zero phases. Accordingly the phase characteristics of the emitted probing signals do not affect the frequency response of the reflected signals. Matter so f interestare cases where probing signals are not in phase. From this point of view are considered two four-carrier probing signal shown below

$$S_{1PS}(t) = \cos(\omega t) + \cos((\omega + \Omega)t) + \cos((\omega + 2\Omega)t) + \cos((\omega + 3\Omega)t) \tag{6}$$

$$S_{2PS}(t) = \cos(\omega t) - \cos((\omega + \Omega)t) + \cos((\omega + 2\Omega)t) + \cos((\omega + 3\Omega)t) \tag{7}$$

Both $S_{1PS}(t)$and$S_{2PS}(t)$ signals have identical frequency response and the peak-factor (the ratio of the maximum power at any given time-"peak" to the average power) of $S_{1PS}(t)$is greater than the peak-factor of $S_{2PS}(t)$a little more than twice. The intensity of the reflected signal (in the band $2\omega$to$2\omega+6\Omega$) from probing signal $S_{2PS}(t)$is two times smaller compared to the intensity of the reflected signal from probing signal $S_{1PS}(t)$. Moreover, in the spectrum of the reflected signal in the case of using $S_{2PS}(t)$some spectral components vanish.

Increasing the power of the reflected signal *N* times can be achieved only with maximum possible peak factor, i.e., when all spectral component so f the probing signal are in phase.

When a pulse signal with a duty cycle equal to the required peak-factor (*N*) the power of the reflected signal is *N* times greater compared to using a continuous signal while maintaining the same average transmission power for both continuous and pulse signals. The same applies o the power of the reflected signal of multi-carrier radiation if all products in nonlinear frequency range from$2\omega_1$to$2\omega_N$ are taken. It can be concluded that when comparing the performances of different probing signals with the same average power, it is advantageous sin terms of power of the reflected signals the one with greater peak-factor. This applies to the comparison of all statements: using multi-carrier and single-carrier probing signals.

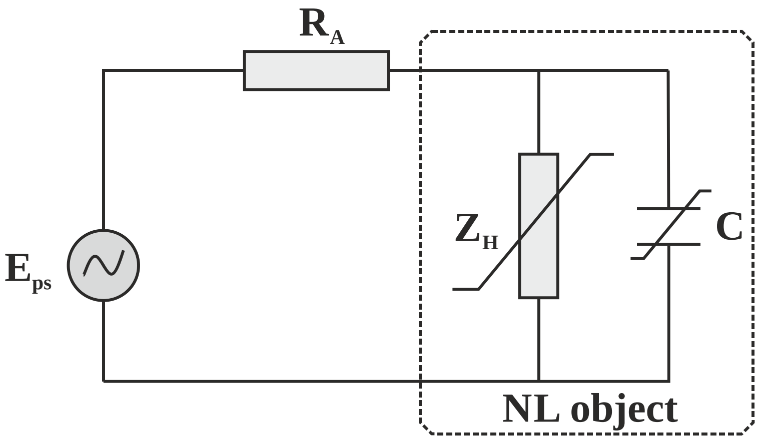

FIG. 1.

FIG.1 shows an equivalent circuit of an ideal non-linear object (*NO*), where in the E_{PS} is the electromotive force caused by the probing signal, R_A is the resistance of the linear portion of the radiation and the U_{NO} is the voltage on the non-linear object. All of these voltages are related with the flowing current *I* with volt-ampere characteristic $I = f\ (U_{NO})$.

Transmit power of the ideal nonlinear object is

$$P_{NO} = R_A(I_{NO})^2 \tag{8}$$

Of interest is the spectrum of the current flowing through then on linear object. The reforce the relationship between the current flowing through the non-linear object and current based on probing signal must be determined

$$I = I(E_{PS}) \tag{9}$$

Kirchhoff equation for perfect non-linear object has the form

$$E_{PS} = IR_A + U_{NO} \tag{10}$$

The function $U_{NO} = f^{-1}(I)$ is determined as the inverse volt-ampere characteristic of the nonlinear object. By substituting it with (10) we get

$$E_{PS} = IR_A + f^{-1}(\mathrm{I}) = \mathrm{F}(\mathrm{I}) \tag{11}$$

Function (11) is the inverse relationship of the requested function (9)

$$I = F^{-1}(E_{PS}) \tag{12}$$

Analytical determination of the magnitude of the current in (12) is difficult. In computing environment that corresponds to a conversion of recorded file sand finding their spectrum sing a fast Fourier transform.

CONCLUSIONS

Calculations show that in linear mode of interaction of probing signal with nonlinear object the combined power of the reflected signal for products of second order (second harmonic for each carrier frequency of the probing signal –$2\omega_1$, $2\omega_2$,...,$2\omega_N$) is always equal to the power of the second harmonic of single-carrier signal if the average powers forsingle-carrierandmulti-carrierprobingareequal.Accordingly,the phase differences do not affect the power but influence the shape of the spectrum. Regarding the two signals(6)and(7)the combined power of signals reflected from non-linear object are approximately equal. In modes close to the saturation of then on-linear element the power of the reflected signal increases significantly for probing signals with low peak-factor. This is also valid for single-carrier probing signals with a small peak-factor [3]. Further more, the spectrum of the reflected signal is so blurred that impedes optimal reception of the reflected signal.

As a result of the calculations should not expect higher power of the reflected signal with the use of multi-carrier probing signals compared to single-carrier. That is why for real experiments are mostly used single-carrier probing signals.

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