A NOVEL SCHEME OF FM DETECTION USING AN ACTIVE PATCH ANTENNA

S Chatterjee(1), A Bhattacharya(2) and B N Biswas(3)

(1)Sugandhya High School, Hooghly-712102, West Bengal, INDIA

(2)Vivekananda Mahavidyalaya, Burdwan, West Bengal, INDIA, apala_2003@rediffmail.com

(3)Academy of technology, Hooghly-712121, West Bengal, INDIA, baidyanathbiswas@yahoo.com

ABSTRACT

An Active Microstrip Patch Antenna (AMPA) integrated with a Gunn diode is basically a negative resistance oscillator but with an arrangement for transmission and reception of a signal that is allowed to shine on the patch. And as under appropriate condition the AMPA can be locked to the incoming signal. Within the synchronization range AMPA losses its identity and obeys the command from forcing signal. Over the lock band the active antenna aside following the instantaneous phase of the incoming signal exhibits the phenomenon of FM-AM conversion. In this paper both the amplitude and phase information are use for detection of an FM signal. The proposed arrangement is not only able to detect information signal from a feeble microwave signal but also increases the efficiency of detection considerably.

INTRODUCTION

Active Microstrip antennas are potentially attractive for realizing large aperture phased array antennas suitable for Satellite and space based communication [1], short-range microwave communication, LAN's microwave identification system etc [2]. An Active antenna is basically an oscillator and then a radiator, and as such its device characteristics under injection locked condition shows the following features [3].

1. The oscillator phase faithfully follows the phase variation of the incoming signal.
2. FM-to-AM conversion is observed i.e. the amplitude of the synchronized oscillator varies almost in accordance with the frequency modulation of the synchronized signal.
3. An injection locked oscillator discriminates against interfering signal accompanying the synchronizing signal.
4. The device current within the lock band shows a square law dependence on the instantaneous amplitude of the antenna or oscillator output – called Current Valley phenomenon.

All these features are the ingredients of a tracking FM receiver. In this paper all these properties are judiciously used to develop an active antenna to an efficient receiver.

MECHANIZATION OF THE PROPOSED SYSTEM

The scheme is shown in Figure-1. The upper channel uses the FM-AM conversion property to extract the modulation signal. This is achieved in the following way. Remembering the current valley property of a synchronized oscillator,

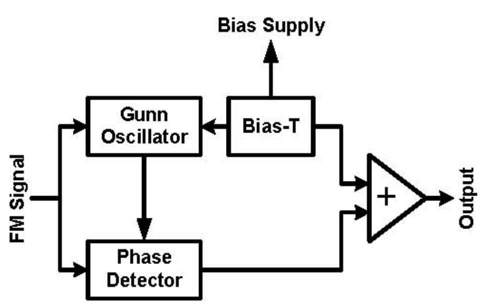

Fig.1: The new lock-in Demodulator

i.e., the average device current being proportional to the square of the instantaneous amplitude of the oscillator, it is not difficult to appreciate that this performs the function of square law detection. Therefore, the low frequency output across the bias-T gives the demodulated output. The lower channel of the Figure-1 picks up the information in the instantaneous phase of the synchronized oscillator. It is known that under locked condition the phase of the Gunn oscillator faithfully follows the phase modulation of the incoming signal. The output the two channels are added – thus resulting in an increased strength of the received signal.

PHYSICS OF INJECTION SYNCHRONIZATION

An Active Microstrip antenna integrated with Gunn diode can be thought to be similar to a Gunn Oscillator. A parallel equivalent circuit of Gunn oscillator in presence of an injection locked signal is shown in Figure-2. In drawing

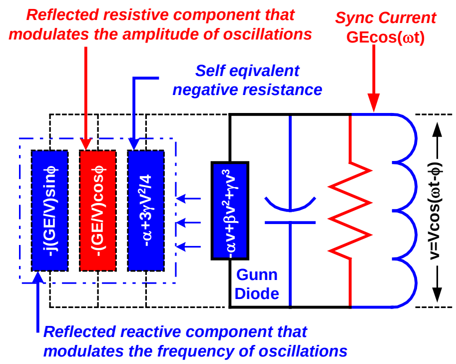

Fig.2: Analytical Equivalent of a Gunn Oscillaor and Physics of Injection Synchronization

the equivalent circuit it has been assumed that the oscillator output in presence of the synchronizing signal, given by

$$\begin{aligned} I_{inj} &= I\cos(\omega t) = GEc\cos((\omega t-\varphi)+\varphi) \\ &= [GE\cos\varphi]\cos(\omega t-\varphi) + [GE\sin\varphi]\sin(\omega t-\varphi) \end{aligned} \quad (1)$$

is taken of the form

$$v(t) = V(t)\cos(\omega t-\varphi) \quad (2)$$

Where $I = GE$, and G is the passive conductance of tank circuit of the oscillator. In writing the oscillator output in form of (2), the center frequency of the injected frequency modulated signal is assumed to be close to the free running frequency of the oscillator. The relation (1) clearly indicates that the synchronizing signal injects an In-phase as well a Quadrature component of current into the oscillator, which is represented by a parallel tuned circuit along with the equivalent nonlinear conductance of the diode. Here, a parallel tuned circuit has analytically replaced the patch antenna with the inductive element as L; C represents the capacitive element and G is passive conductance. The In-phase and Quadrature components of injection current can be thought to reflect conductance of value –(GE/V)cosφ and reactance of value -(GE/V)sinφ, both of which depend on the oscillator output, synchronizing input and the instantaneous phase difference φ. Thus depending upon the values of these values the amplitude and as well as instantaneous frequency of the oscillator is modulated. As a result the instantaneous frequency of the oscillator is pulled towards that of the synchronizing signal. If the frequency difference is appropriate and amplitude ratio is adequate then the local oscillator will be synchronized with the incoming signal.

SYSTEM EQUATION

Therefore, the governing equation can be derived writing the current equation as

$$GE\cos\varphi + jGE\sin\varphi = \left(-\alpha + \frac{3}{4}\gamma V^2\right) + Y(j\omega) \quad (3)$$

Where

$$\begin{aligned} Y(j\omega) &= G\left[1 + j\frac{2Q}{\omega_0}(\omega-\omega_0)\right], \textit{ and} \\ j\omega &\Rightarrow j\left(\omega - \frac{d\varphi}{dt}\right) + \frac{1}{V}\frac{dV}{dt} \end{aligned} \quad (4)$$

Where α and γ are constants defining the current voltage relation of the Gunn diode.

Using (1) through (4) it is easily shown that

$$\frac{dV}{dt} = \frac{\omega_0 V}{2Q}\left(\alpha - \frac{3}{4}\gamma V^2\right) + \frac{\omega_0}{2Q} E\cos\phi \tag{5}$$

and

$$\frac{d\phi}{dt} = (\omega - \omega_0) - \frac{\omega_0 E}{2QV}\sin\phi \tag{6}$$

If the incoming signal is of the form $I\cos(\omega t + \theta)$ then the amplitude equation of the AMPA remains the same as (5) but the phase equation takes the following form

$$\frac{d\phi}{dt} = (\omega - \omega_0) - \frac{\omega_0 E}{2QV}\sin\phi + \frac{d\theta}{dt} \tag{7}$$

Where ϕ denotes the phase difference between the forcing signal and the AMPA output. It is easily shown from the above equations that AMPA is locked to the external signal provided

$$\omega - \omega_o \leq \frac{\omega_o E}{2QV} \tag{8}$$

Further when the above equations i.e. (5) and (7) are numerically solved show that under appropriated locked condition, *(i)* the instantaneous frequency of the AMPA faithfully follows the input instantaneous frequency variation and *(ii)* the input frequency variation is translated into amplitude variation of the AMPA (i.e. FM-AM conversion). Thus, the incoming angle modulation of the FM signal can be recovered both the information embedded in the amplitude and instantaneous frequency of the AMPA. This is what is illustrated in Fig.1.

SIMULATION RESULT

Numerical experimentation has been performed with MATLAB. This is done in the following way. Output of the AMPA is divided into two parts: one part i.e. the amplitude modulated part of the FM –AM signal is subjected to Square law detection, the other part i.e. the phase modulated part of FM-AM converted signal is mixed with FM signal in a Mixer. The information signal is obtained by passing the mixer output through suitable Low pass filter. Then the two signals (One obtained from the square detected output and another from the phase detector output) are then added. As a result the signal strength is increased to a great extent. The detected signal is in the same phase with the information signal. The detected information signal obtained from the square law detected output; phase detector output and the resultant (from the adder output) are shown in Figure-3.

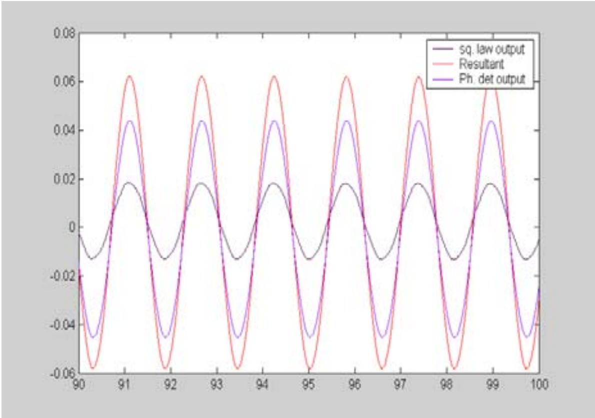

Fig.3: Simulation result showing the performance of the proposed demodulator

CONCLUDING REMARKS

A new physical approach is given in deriving the governing equation of in injection synchronized AMPA. Simulation results clearly demonstrate that the Information signal obtained from the Square law detected output and from the Phase detector output are in the same phase. The strength of the information signal obtained from the adder output is much more than the Information signal obtained from the Square law detected output and from the Phase detector output. So the arrangement is not only able to detect information signal from a feeble microwave signal but also increases the efficiency of detection considerably.

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