PHASE MEASUREMENTS AND CHARACTERIZATION FOR UHF MOBILE RADIO CHANNELS

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1. Introduction

To measure and characterize the phase behaviour of mobile radio channels is of great interest for the design and implementation of the most efficient mobile radio digital systems, and in particular for the design of optimal carrier recovery schemes in the presence of Doppler and channel effects, and in the search for optimal modulation and coding techniques.

This paper describes the techniques used for phase measurements for CW transmissions over a mobile radio channel at 910 MHz over a mixture of open suburban and urban areas in the Quebec city region; it gives samples of phase recordings, and presents a preliminary statistical analysis for two recordings, one taken in an open suburban area and the other in the center of an urban area.

2. Measuring and recording system

In a nutshell, the measurement system is based on the use of two very stable 5 MHz reference oscillators, one at the transmitter and one at the receiver. These oscilloquartz oscillators, when kept powered as was the case here, possess a frequency stability of the order of 10^{-12} over a period of a few hours.

Figure 1 represents the transmission equipment: a highly stable 5 MHz oscilloquartz was used to pilot an HP-8663A signal synthesizer generating a 910 MHz signal in a 6 watt amplifier and a 3 dB cellular mobile radio car antenna. The receiving equipment is illustrated in block diagram form in figure 2. A 5 MHz reference oscilloquartz was used to pilot a HP-8673C signal synthesizer providing the Local Oscillator signal at 910.455000 MHz to a HP-8902A test receiver. This LO signal was mixed in the receiver with the incoming 910 MHz signal (now affected by Doppler shifts and phase effects) and down converted to an IF frequency of 455 kHz. This 455 kHz IF signal (affected by Doppler shifts and phase effects) was itself mixed with a reference in phase and with a reference in quadrature at 455.000 kHz: these references were provided by Rockland 5100 frequency synthesizers, controled by the 5 MHz oscilloquartz. After the mixing and low-pass filtering illustrated on figure 3, one obtained the baseband I and Q signals, which were simultaneously sampled, converted by a 12 bit A/D converter and recorded in a micro-computer. Odometer pulses were also recorded.

The module A and the phase Φ are then calculated as follows:

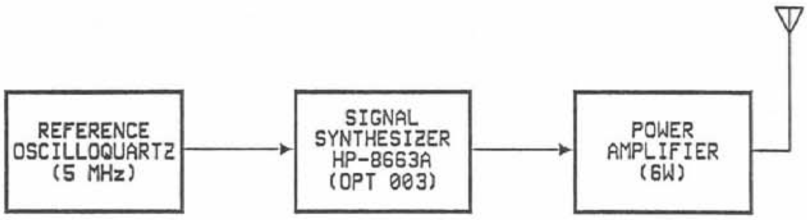

Figure 1. Transmission system

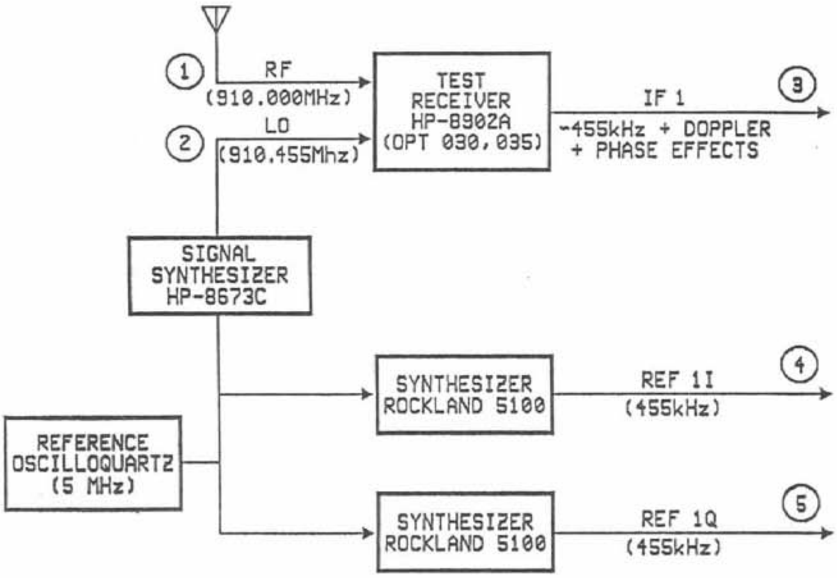

Figure 2. Receiving system

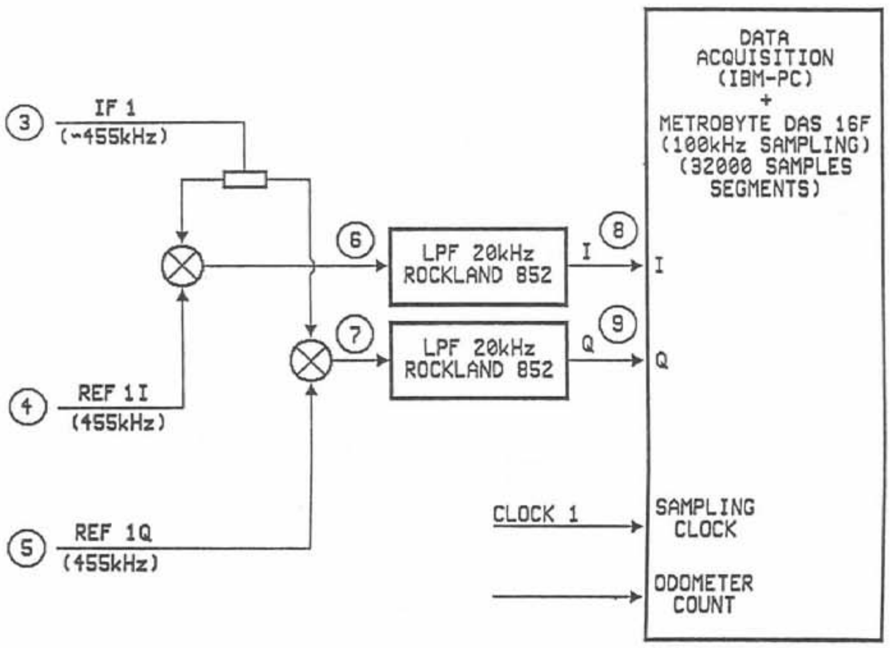

Figure 3. Recording system

$$|A| = \sqrt{I^2 + Q^2}$$

$$\Phi = \text{arctg}(Q/I)$$

The receiving system can be easily calibrated when the mobile unit (hence the receiver) is stationary and when there is little vehicle movement in the vicinity of receiver antenna: in that case, the I and the Q signals appear as horizontal lines on the screen of the osciloscope. In X-Y mode, the I and the Q will give a point on the oscilloscope screen: and if the vehicle starts moving slowly in an area with little reflections from surrounding cars and buildings, this point will rotate in a circle, making as many circles per second as the Doppler frequency shift. For testing purposes, this circle can be observed with the vehicle stationnary if one simulates a Doppler frequency shift. For example, the Local Oscillator Frequency can be changed by 1 Hz from 910.455000 MHz to 910.455001 MHz: A circle is then drawn on the oscilloscope screen, once every second.

3. Measurement results and preliminary analysis

Figures 4, 5 and 6 show segments of approximately 0.2 second duration of phase measurements. Figure 4 corresponds to a recording at 70 km/h on an expressway oriented more or less along the direction of signal incidence in an open suburban area 25 km from the transmitter: the signal is obviously very clean and there is little else to observe as the linear Doppler shift due to the vehicle displacement relative to the transmitter. Such is not the case in figures 5 and 6, where major channel effects including phase reversal are clearly noticeable. Figure 5 is a segment of a recording taken at 30 km/h an a main street in the city center oriented close to the direction of signal incidence some 5 km from the transmitter. The recording of figure 6 was taken at 30 km/h on a street in an urban area transversal to the direction of signal incidence at 2.5 km from the transmitter.

Let us conclude by presenting in Table I an example of statistical analysis of phase variations for two data files, A and B of approximately 6 seconds duration. File A is recorded on an expressway in a fairly open suburban area 3 km from the transmitter. For such an environment, the instantaneous phase variations (between successive samples) are very small: in more than 94% of the cases, the phase variations are less than 5 degrees. File B shows a very different story. The recording is taken on a main street in the city center, some 4.5 kilometers from the transmitter site. The phase variations are extremely severe, exceeding 45° in more than 6% of the cases, and 90° in more than 1.5% of the cases. 180° phase reversals are also observed.

The following definitions have been used for this statistical analysis of the phase variations:

$$\Delta\Phi_i = (\Phi_{i+1} - \Phi_i) + (\Phi_{i-1} - \Phi_i)$$

$$\Phi_i = \text{arctg}(Q_i/I_i)$$

Note that this definition has the effect of eliminating a constant Doppler shift, so that these phase variations represent the channel effect, not the effect of the Doppler shift.

This example of statistical analysis is a first attempt at describing the statistical behaviour of the phase variations due to channel effects (multipath). Although, a more rigourous analysis is required, the evidence points to some kind of gaussian distribution of the instantaneous phase variations, whose variance is certainly a function of the density of the urban area and possibly of other factors such as street orientation.

Table I

Phase variation $\Delta\Phi$	FILE A	FILE B
$P(\Delta\Phi > 5°)$	.03602	.74038
$P(\Delta\Phi > 10°)$	.00401	.52115
$P(\Delta\Phi > 30°)$	.00018	.13563
$P(\Delta\Phi > 45°)$	.00000	.06532
$P(\Delta\Phi > 90°)$	.00000	.01696
$P(\Delta\Phi > 135°)$	.00000	.00844
$P(\Delta\Phi > 180°)$	.00000	.00483

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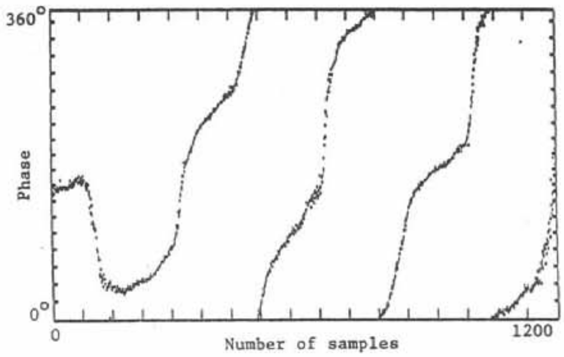
Figure 5



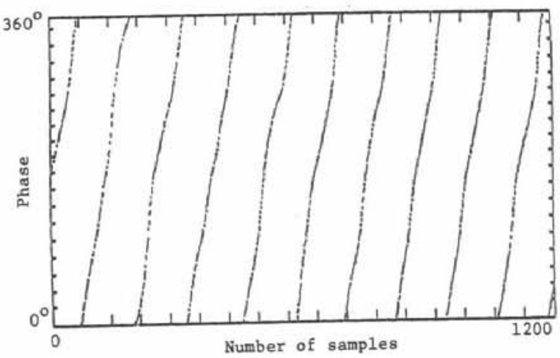


Figure 4

Figure 6