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Group Delay of High Q Antennas

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Abstract—Group Delay variations versus frequency is an essential factor which can cause distortion and degradation in the signals. Usually this is an issue in wideband communication systems, such as satellite communication systems, which are used for transmitting wideband data. However, group delay can also become an issue, when working with high Q antennas, because of the steep phase shift over the frequency. In this paper, it is measured how large group delay variations can become, when going from a low Q antenna to a high Q antenna. The group delay of a low Q antenna is shown to be around 1.3 ns, whereas a high Q antenna has group delay of around 22 ns. It is due to this huge group delay variation characteristics of high Q antennas, that signal distortion might occur in the radio system with high Q antennas.

I. INTRODUCTION

The mobile devices are evolving to provide the user greater flexibility and ubiquitous communications coverage through the inclusion of more communication standards as e.g. LTE. The frequency spectrum for mobile communication has been widened to more than 20 bands, ranging from 700 MHz to 2700 MHz, for use with LTE. Due to the fundamental limitation of antennas [1], the antenna system is a major obstacle in the implementation of successful multi-communication in small mobile devices. One way to overcome this issue, is by applying high Q reconfigurable antennas. High Q antennas have narrow impedance bandwidth characteristics, hence they can be tuned to resonate at different channels. However, high-Q antennas have also relative high current and field density, which results in many design challenges.

Normally Group Delay (GD) is looked into in wideband communication systems e.g. satellite communication systems, which are used for transmitting wideband data, because the distortion causes Signal to Noise Ratio (SNR) or Bit Error Rate (BER) degradation [2]. However, GD can also become a parameter of concern, when working with high Q antennas, because of the big and steep phase change over the frequency. Flat and consistent GD (versus frequency) is important. Generally, it is desired that the spectrum is treated the same over the intended bandwidth of frequencies, otherwise distortion will occur. Large GD ripples may cause

unsatisfactory distortion in the signal in a transmitting radio system. Therefore, in radio system design there is usually a specification for how much a GD that can be accepted.

This paper presents GD measurements of an high Q antenna. Furthermore, the difference in GD between a low Q and a high Q antenna is discussed. The basics of GD is presented in Section II. Section III presents the measured GD of the high Q antenna. The results are shown and discussed in Section IV and finally conclusion is disclosed in section V.

II. BASICS OF GROUP DELAY

Linear distortion happens in linear systems in which the magnitude of frequency response is not constant and the phase of frequency response is nonlinear. Phase distortion is measured using GD [3]. It is expressed in units of time (nanosecond). The GD is related to the phase shift variation with frequency. For a linear system, at an angular frequency of $\omega = 2\pi f$, the GD is defined as $\tau(\omega) = -\frac{\Delta\phi}{\Delta\omega}$. In distortionless systems, the phase characteristics must have a linear slope so that the ratio is constant for all frequencies and this represents a constant GD. However, any deviations from linear phase over the frequency range will cause GD variations. Therefore, for a linear system, linear distortion over a frequency bandwidth is caused by GD variations over that bandwidth, not GD. GD can be construed as a measurement of how long it takes a signal to traverse a network, or its transit time.

In order to find the GD between 2 antennas, the normal practice is to derive $\Delta\phi/\Delta\omega$ from S_{21} phase. However, if GD of a single transmitting antenna is desired, then one way is to simulate the same antenna as receive and transmit and then divide the GD result by two. This is the method used in this paper. When simulating or measuring the two identical antennas, it is important to make sure that the antennas are in the far field region of each other. Since the absorption efficiency of an receiving antenna is not 100% [4], it is recommended that the separation is even larger to make sure that the scattering from the receiving antenna is not affecting the GD result.

III. ANTENNA DESIGN

Two high Q identical patch antennas are designed for this study. Since the investigation is made at 700 MHz, the Printed

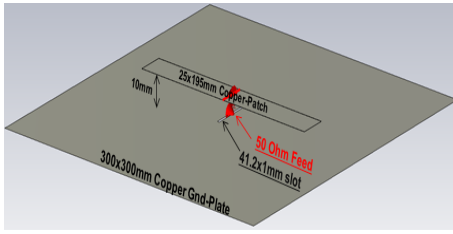


Fig. 1. Geometry of the patch antenna.

Wire Board (PWB) dimensions are chosen to be $300 \times 300 \text{ mm}^2$ (see Figure 1) in order to make sure that the measurement cable effect will not influence the radiation pattern of the antenna, leading to errors in the GD measurement. The patch has the dimensions $25 \times 195 \text{ mm}^2$, and it is placed at 10 mm height from the PWB. A slot, with the dimensions of $41.2 \times 1 \text{ mm}^2$, is made at the center of the PWB. The antenna is excited by placing the feed across the slot, hence soldering is only used at the feed point. The antenna is self-matched, so no matching components are used. For the mock-up, polystyrene is used as support material, not only between the patch and the PWB, but also around the whole structure to make the antenna stable.

The antenna impedance is seen in Figure 2, where the $\text{abs}(S_{11}) = -6 \text{ dB}$ matched bandwidth is 8.3 MHz which corresponds to the $Q = 98$.

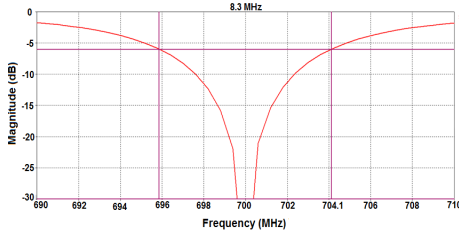


Fig. 2. Log magnitude plot of the antenna impedance.

IV. MEASUREMENT SETUP

Figure 3 illustrates the measurement setup for the S_{21} measurements. As seen the measurements are done in an anechoic chamber in order to avoid that the reflections from the antennas influence the results. The two vertically polarized patch antennas are placed face to face on extruded polystyrene stands. The measurements are done at three different distances between the antennas, 1m, 2m and 3m respectively. This, in order to make sure that the scatterings from the receiving antenna are mitigated to an acceptable level, and will not affect the measurements. Cabling is done in a way so that a minimum influence on radiation pattern can be expected. The vector network analyzer seen on the picture, is used to save the S_{21} data, from which the GD is computed.

V. GROUP DELAY RESULTS

The GD results at 700 MHz are presented in Figure 4. There are small deviations between the three curves, which may be

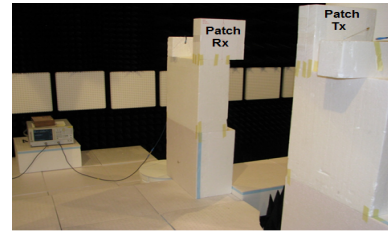


Fig. 3. Measurement setup in the anechoic chamber.

due to the scattering effect of the receiving antenna. The GD variations are large due to the high Q of the antenna, and reaches a maximum of approximately 22 ns. The 22 ns is quite a high number when comparing to a low Q antenna ($Q=6$), which has a GD variations of around 1.3 ns. This high GD variations, due to the steep phase shift over the frequency, may cause unsatisfactory distortion in the signal.

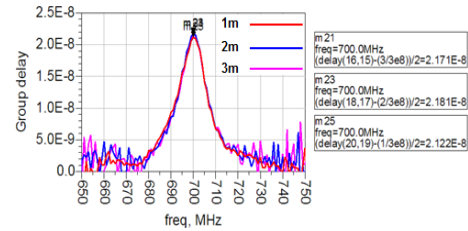


Fig. 4. Measurement of GD at three different separation distances between the two patch antennas.

VI. CONCLUSION

This paper discusses the issues concerning the GD in high Q antennas. It is shown that increased Q of the antenna results in increased variations in the GD, leading to distortion in the signal. Due to the distortion issue, GD can be another limiting factor on top of the already known factors, which will set a limit for how high Q an antenna can have. Therefore, it becomes important to measure the GD when working with high Q antennas in order to verify that the GD variations are within the specifications of the radio system design.

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