COPYRIGHT NOTICE

© 2014 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.

Measurement of Antenna Radiation Pattern using Injection Locking Technique

Md. Hasanuzzaman Sagor, Peter Callaghan
School of Engineering, University of Greenwich, Chatham Maritime, Kent ME4 4TB, UK.
m.h.sagor@gre.ac.uk, p.callaghan@gre.ac.uk

***Abstract*— This paper presents practical results using injection locking to synchronize the local oscillator on a wireless device enabling antenna measurements to be made in a modern anechoic chamber, overcoming the need to connect a cable to the device under test.**

***Index Terms*—Injection locking, antenna measurement, locking oscillator.**

I. Introduction

A major number of applications of radio, and hence antennas, is for portable devices. However, common antenna test methods require a cable to be attached to the antenna. Often this cable can distort the antenna characteristics. Ideally the antenna should be measured in a 'wireless' condition! In this paper we evaluate a novel solution using injection locking that can achieve this.

The usual approach to measure the radiation pattern of an antenna is to use an anechoic chamber. Early systems used a microwave source connected to the Antenna with a detector to measure the radiated field via a suitable receive antenna. To provide a generalized measurement system the detector used was usually a broadband device. This resulted in a high noise floor so early measurement systems were often limited to 20-30 dB of dynamic range. Modern systems use a Vector Network Analyzer (VNA) such that the received signal is synchronized to the transmitted signal [1], allowing narrowband reception and achieving significantly higher dynamic range.

Use of a VNA has the limitation that the Antenna is connected by cable to the VNA. Whilst this is not a problem for large antennas, attaching a cable to a small device containing an integrated antenna can lead to erroneous results. The cable can change the flow of current on the 'ground plane'. Indeed it has been shown that the ground plane current can be a significant parameter contributing to the radiation pattern [2] and for correct characterization the complete device should be measured - with no cables attached! A solution is to use a local oscillator (LO) on the device under test (DUT) to provide the radiating signal, such that no cables need be attached. However, this LO must to be synchronized to the VNA signal for measurements. We propose using injection locking technique [3-5] to accomplish this and present initial results demonstrating the feasibility of this method.

II. Measurement Technique

Fig. 1 presents an outline of the proposed technique. Usually a signal from port 2 of the VNA is attached directly to the test antenna and the radiated signal is received by a second receive (RX) antenna and fed back to port 1 of the VNA. The VNA calculates the scattering parameter S12 that can be passed to a pattern controller, providing both amplitude and phase of the radiated pattern. We propose that the antenna being tested is integrated into the wireless device under test (DUT) such that the signal radiated is from an internal LO. To synchronize this LO to the VNA a locking signal from port 2 is fed to a second 'transmit' (TX) antenna inside the chamber that couples the locking signal to the LO via radiation.

In principle this method should be straightforward, but there are some potential problems that are investigated here. As the locking signal is radiated it can also be received by the RX antenna – forming an interfering signal, that will distort the measurement. Secondly for pattern measurement the DUT is rotated in the chamber, presenting a practical problem of ensuring there is sufficient coupling between the DUT and the TX antenna to ensure the LO remains locked.

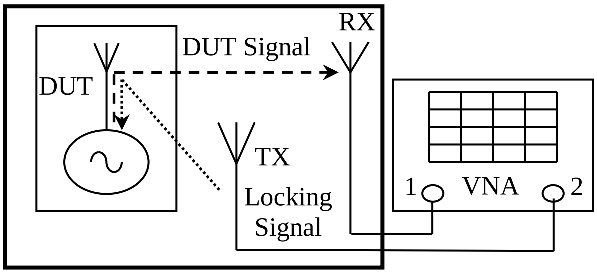


Fig. 1: Proposed Injection Locking Measurement System

To evaluate the proposed method, measurement of a simple 2.4 GHz dipole a dipole antenna of 62mm length was undertaken. For injection locking, a commercially available 2.4 GHz oscillator (Z-communications SMV2490L) was used for the LO. The antenna was fed by a short cable from the locking oscillator as shown in Fig. 2. This feed cable included a simple twin-wire λ/4 balun. With this arrangement the co-polar radiation pattern of the antenna (Ey) around the x- axis could be measured either with the LO or independently attaching a cable directly to antenna, with no expected significant distortion of the radiation pattern.

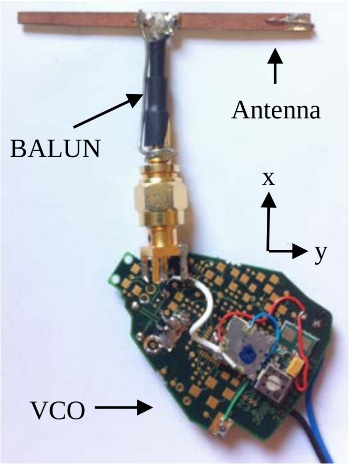


Fig 2: 2.4 GHz voltage controlled oscillator and dipole antenna

The setup of the experiment inside the anechoic chamber is shown in Fig. 3. To provide a locking signal from the VNA, a directive horn antenna was placed facing towards the DUT. The horn antenna was mounted on the rotating platform of the anechoic chamber, so that it rotates with the DUT during pattern measurement. The horn radiates a linearly polarized signal and the arrangement in Fig.3 ensures that there is maximum coupling as the locking signal is in the 'omni-directional' plane of the dipole pattern. A horn was chosen as it has a directive pattern such that direct radiation to the received antenna is minimized.

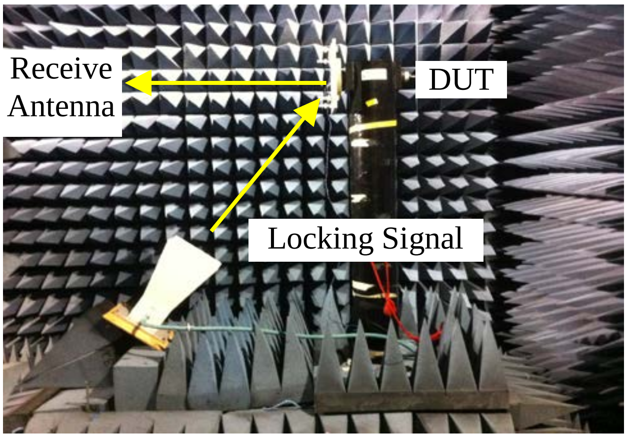


Fig. 3: Experiment setup inside the anechoic chamber

The received signal to the VNA was also connected, via a splitter, to a Spectrum Analyzer. This provided a means of checking that the LO signal remains locked to the VNA signal during the measurement. It is important that the signal remains locked throughout the whole measurement. If it loses lock for any period of the measurement the signal will be attenuated by the VNA filtering, distorting the radiation measurement.

III. Results and Discussion

A. Locking Bandwidth

The locking bandwidth mostly depends on the power of the injection signal. The greater the injected power, the wider the locking bandwidth [4]. Fig. 4 below shows the relation between the NWA power level and locking bandwidth achieved in this set-up. A minimum of -20 dBm is required to achieve injection locking, although due to the narrow locking bandwidth the LO could easily lose lock (i.e. with frequency drifts caused by vibration and temperature). In practice for this set-up a minimum signal of -10 dBm was determined. A higher level could be used, but this could potentially introduce an interfering signal in the chamber. The LO power level was +13 dBm, hence NWA levels of +10 dBm are comparable to the LO level.

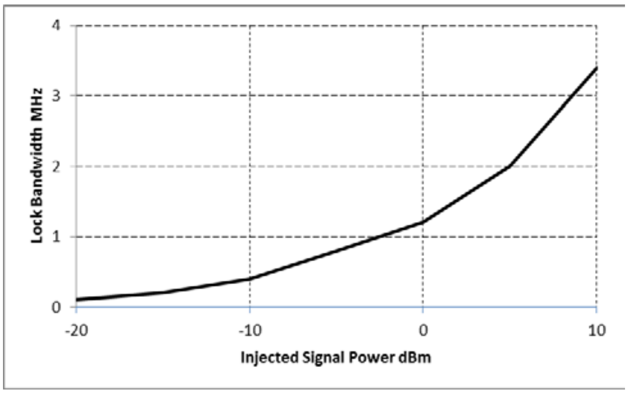
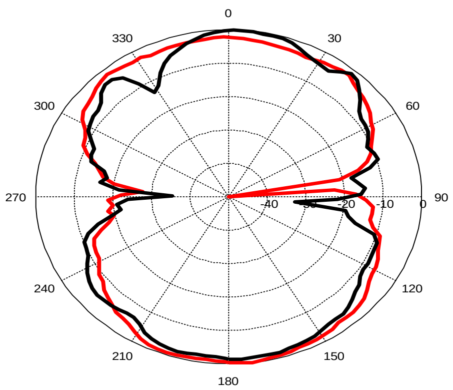


Fig. 4: Injected power vs Locking bandwidth

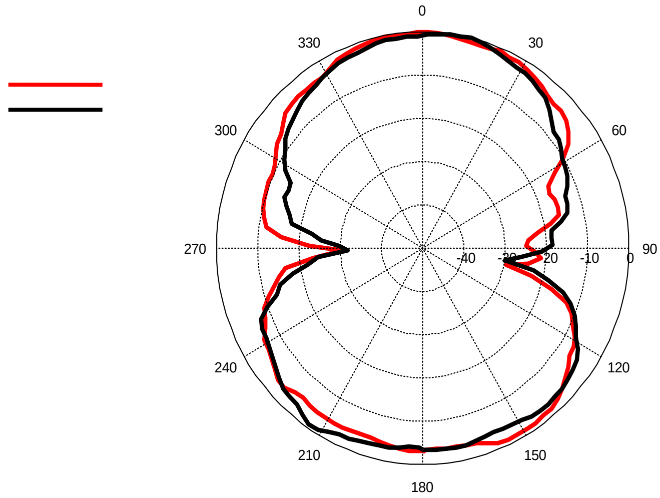
B. Radiation Pattern

The radiation pattern of the 2.4 GHz dipole antenna was measured conventionally by attaching a cable and then by using proposed injection locking technique. The measurement was carried out for different power levels of injected signal, ranging from the minimum of -10dbm to +10dbm. The measured patterns are presented in Fig. 5.

It can be observed from this normalized polar plot that there are discrepancies between the measurement data when the injection locking signal is at +10dbm. At this level the leakage signal from the horn antenna to the receive antenna is about -10dB below the radiated signal from the DUT, causing interference. This is particularly apparent at 330º in Fig. 5(a) – as the test platform rotates the horn antenna is facing towards the receive antenna (in Fig. 3 it is shown at 0º, pointing directly away from the receive antenna). This clearly demonstrates a potential problem with the proposed method. However, reducing the locking signal power to -10dbm reduces the interference. The -10 dBm measurement is seen to be close to the ‘conventional’ measurement in Fig. 5(b). Indeed the injection locked measurement is closer to the ideal ‘doughnut’ shape suggesting that the attaching cable for the conventional approach is causing some minor issues.



(a) Injecting signal Power 10dbm



(b) Injecting signal Power -10dBm

Fig. 5: Measured radiation patterns
Antenna connected directly by cable to VNA
DUT Injection Locked to VNA

IV. CONCLUSION

A new method of measuring antenna radiation patterns of wireless devices has been proposed. A small dipole antenna along with a voltage-controlled oscillator has been used as an example to demonstrate the usefulness of this method. The measured result has validated that this technique gives similar or even better radiation pattern avoiding a cable attached to the DUT. Hence, the difficulty to measure a battery operated wireless device by conventional method in anechoic chamber can be performed by using this alternative method for antenna radiation pattern measurement.

REFERENCES

[1] Agilent Technologies’ Inc : ‘Network Analyser Basics’, 2004, [Accessed 10th October 2013]: http://cp.literature.agilent.com/litweb/pdf/5965-7917E.pdf

[2] Callaghan, P.; Sagor, M.H.; Batchelor, J.C., "Control of ground plane influence on antenna radiation pattern for mobile handheld devices," *Antennas and Propagation Conference (LAPC), 2011 Loughborough* , vol., no., pp.1,4, 14-15 Nov, 2011, doi: 10.1109/LAPC.2011.6114127

[3] R. Adler, “A study of locking phenomena in oscillators,” Proc. IEEE, vol. 61, pp. 1380–1385, Oct. 1973.

[4] K. Kurokawa, “Injection locking of microwave solid-state oscillators,” Proc. IEEE, vol. 61, pp. 1336–1410, Oct. 1973.

[5] Razavi, B., "A study of injection locking and pulling in oscillators," *Solid-State Circuits, IEEE Journal of* , vol.39, no.9,pp.1415,1424,Sept.2004,doi: 10.1109/JSSC.2004.83