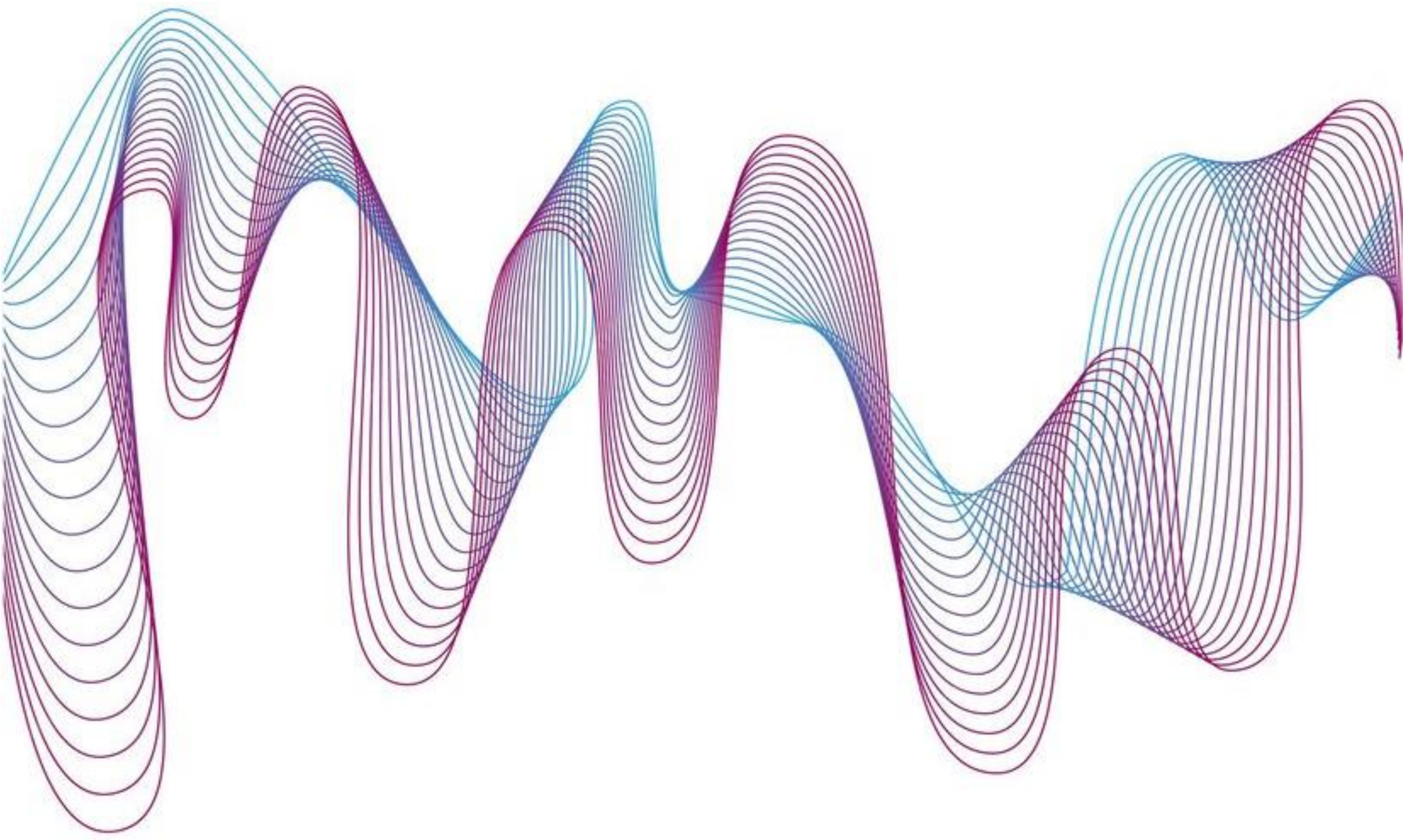
WHITE PAPER

Destructive effects of Vibration on Mobile telecom signals



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Abstract

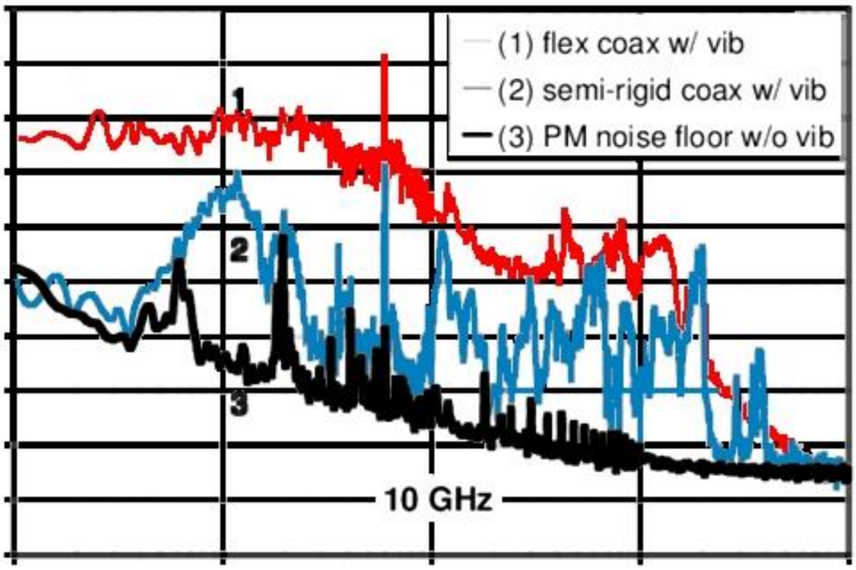
England built the world's first commercial telegraph in 1837, we made the first transatlantic call in 1927; a Uk programmer sent the world's first text message to a mobile phone in 1992 [1].

Our forebears were great telecoms innovators, yet according to research firm Open Signal we rank 46th in the league of 56 developed nations in terms of download speed, making us the worst mobile service in the affluent world.

Active kit by and large performs equivalently across all countries, Network design is a fairly standard set of calculations applied Internationally and environmental conditions in the UK are no worse and probably more benign than other countries, so why do we stand out in this negative way?

Destructive effects of Vibration on Mobile telecom signals

Our previous paper [1] dealt with the triboelectric effect and phase modulation often created by vibration and flexure in mobile phone infrastructure. Hati, Nelson & Howe [2] have published data showing the effects on 10GHz transmissions using typical short length (10cm) cables vibrated at 10Hz that may approximate MIMO type applications.



Residual PM noise floor of the measurement system under vibration for semi-rigid coaxial and braided-shield, flexible coaxial. The DUT is replaced by 10 cm-long semi-rigid coaxial cable for this test. A random vibration profile of acceleration PSD = 1.0 mg 2 /Hz (rms) is used for 10 Hz ≤ fv ≤ 2000 Hz. The bottom curve shows the noise floor measured under no vibration. Narrow spurs are power-line EMI pick-up and should be ignored.

This current short review starts to look at real antennae vibrations to determine actual frequencies and amplitudes encountered in the field to determine whether these are likely to be of concern.

Little formal information appears to have been published – mainly due to the problems of obtaining vibrational data. However, Ying Wang, James Brownjohn et al [3] have developed digital photographic analysis techniques that allows low cost (initially short duration) imaging and data processing methods to determine these typical frequencies and amplitudes experienced in (specifically) larger antennae installations. Although the values may differ in DAS, MIMO and Massive MIMO applications (see the Hati, Nelson & Howe results), the wind forces as described in our earlier publication [4] are clearly already causing significant vibration in the physical infrastructure that apart from damage to the antennae itself adversely affects flexible cabling in the electronic and electromagnetic systems which leads to gross signal degradation through cable and connector failures as well as creating phase and noise signalling errors.

Abbreviated results obtained in Ying Wang, James Brownjohn et al's investigations are shown below and demonstrate quite gross amplitudes at a variety of frequencies with dominant vibrations at <10Hz.

The longer cable lengths common in current antennae installations –often 1-3m in length - are likely to exhibit much larger amplitudes of multi-frequency vibrational modes generating significantly increased noise frequencies – damping of which is of increased importance to prevent major signal distortion.

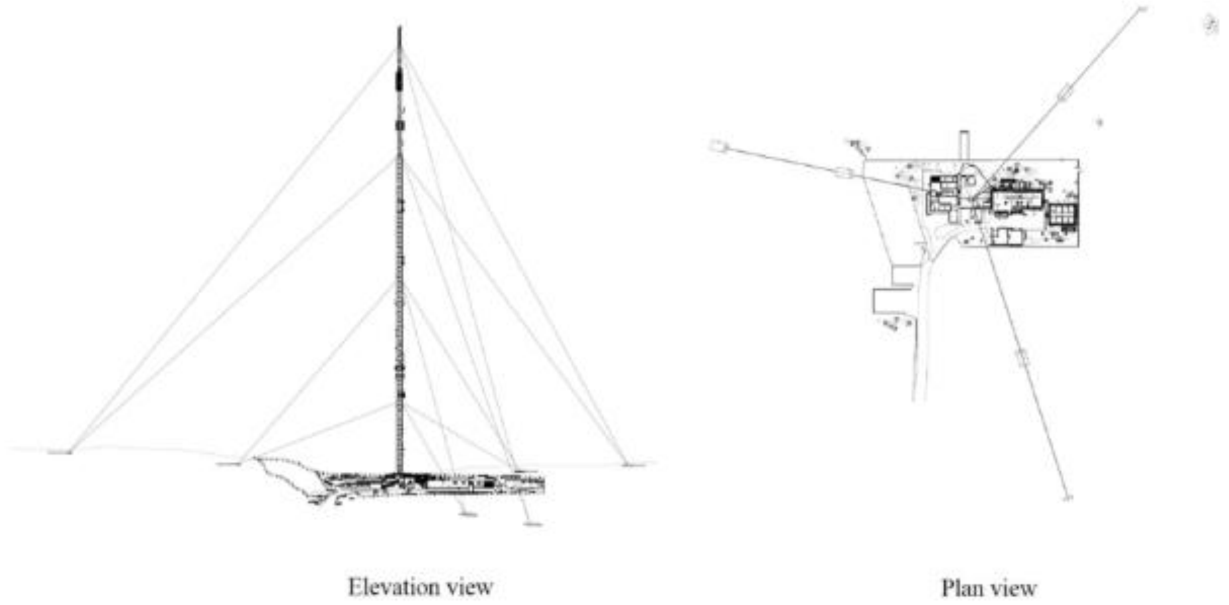


Fig. 1 Typical high guyed mast

Fig 1 shows a typical high guyed mast with the supporting guy cables. These have their own vibrational modes shown below – as seen in the two series of graphs (Figs 4 & 7 below), the various guys display different fundamental vibration frequencies that may then be coupled to the antenna and cabling.

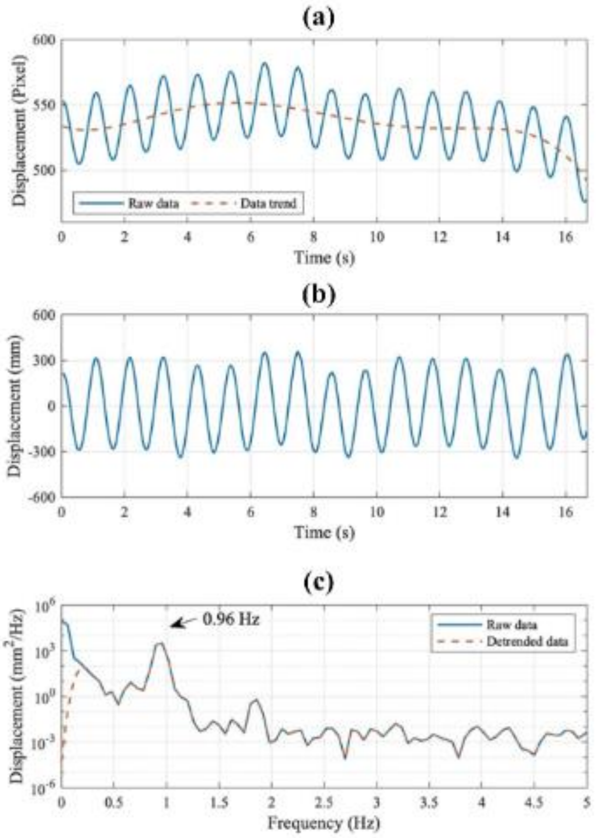


Fig. 4 **a** Original vibration history, **b** detrended data, and **c** PSD of a section of the high guyed mast cable

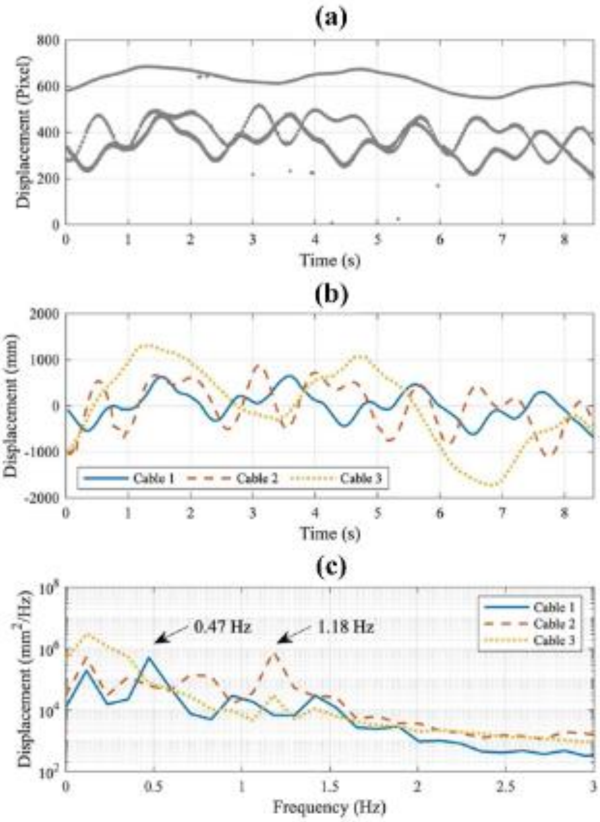


Fig. 7 **a** Raw data obtained with binarisation, **b** separated data, and **c** PSD of multiple cable galloping

What vibration is actually seen at the antennae tip?

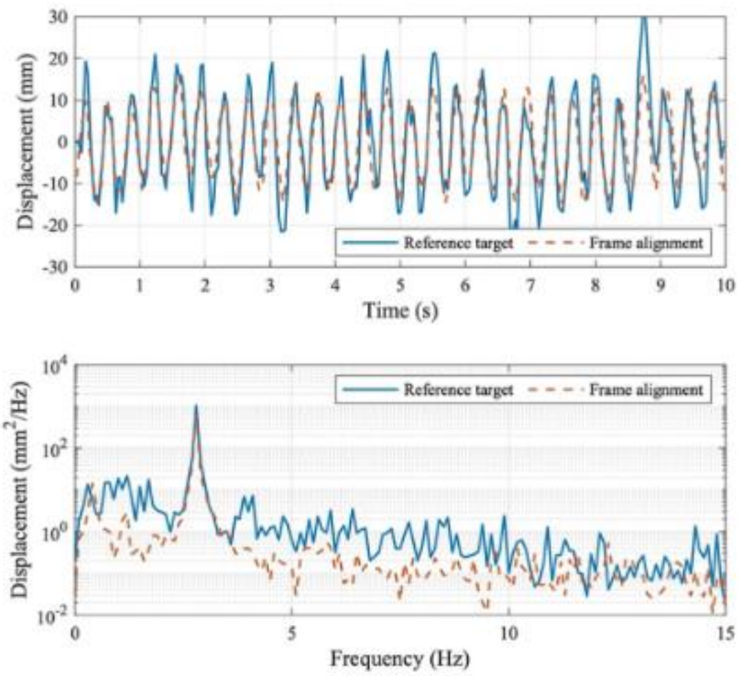


Fig. 16 Vibration data of antenna tip obtained with different methods

These (albeit limited) results suggest that an antenna on a high mast experiences significant amplitude (upto +/-30mm) vibration at (in the test case) ca 2.5Hz. This quite constant pulsing is passed into transmission cables and - even in relatively benevolent wind conditions - causes triboelectric/static effects as well as phase distortions and mechanical degradation of the cables and connectors. Further research data is required to explore the upper limits of these vibrational amplitudes experienced under high wind conditions and with other structural and antennae configurations/types. However, it is clear that mechanical infrastructure is prone to (generally) Low Frequency resonant behaviour when driven by wind – as will any unrestrained cabling and connector systems.

It should be noted that, due to the relatively simple data capture methods employed, the above amplitudes are referenced to the base of the antenna proper rather than the fixed mast ground mount position, so real antenna tip vibrational amplitudes are likely to be significantly higher and have more complex frequency components that will further exacerbate the negative effects.

Below: Some typical MIMO antennae are shown. It may be noted that mountings often appear quite flimsy and cables are generally not well constrained. The MIMO mountings vibrate,albeit at different frequencies to tall masts. All these vibrations are transmitted into cabling and interconnects, adding to the intrinsic microhonics and ‘noise’ frequencies resulting from direct enviromentally -driven cable movement. These noise frequencies are amplified by use of rigid outdated clamp designs in general use and passed into the crucial signal pathways through the all important interconnect transmission media. In addition excessive lengths of hanging and looped cables (not always respecting bend radii) in exposed positions are subject to gross impact noise resulting in undesired noise signals and desired signal distortion. It is a well understood phenomenon that cables don’t differentiate between undesired signal noise and desired signals, they transmit both with impunity, thereby cluttering available bandwidth with undesired noise signal transmissions and reducing available bandwidth for desired data, in turn slowing down our networks. *

In addition, ongoing high-tech updates to networks make them progressively more sensitive to such effects - higher frequencies, shorter range, greater number of antennae, exponentially larger number of interconnects (cables and connectors) – now subject to greater extremes of environmental conditions make them even more susceptible to signal corruption by creating more opportunities for PIM/poor VSWR, triboelectric static, antennae vibration and resultant phase distortion - all associated with data corruption and error correction signalling that reduce data rates to far below theoretical capabilities of componentry.

It is clear that there is an urgent need for much better antenna and cable vibration/movement control to prevent accelerated ageing and signal degradation through the mechanisms discussed in this and previous Hughes papers.

Improved cable construction, routing and lengths, better stress relief of cable interconnects and vibration damped clamping and fixings reduces cable vibrations, contributing to longer field life and faster data rates that better approach theoretical maxima in addition to a reduction in ageing and maintenance costs.

* The density of urban populations in the UK creates a need for significant higher density cabling infrastructure compared to countries with a larger landmass. This exacerbates the issues highlighted

in this paper, and taken together, it may not be so surprising that the UK is near the bottom of the league table for successful high data download speeds being ranked 46th of 54 developed nations.

Typical MIMO Antennae

Massive MIMO installations already demonstrate similar issues

Typical poorly restrained looped cables

Practical Solutions

After significant research into these problems, Hughes have developed anti-vibration systems such as OneClamp to provide significant vibration attenuation of distortive microphonic effects via the incorporation of patented engineered synthetic rubber dampeners into the clamping components. A straightforward change to this more advanced product with it's noise attenuating effects designed to absorb upto 94% of vibration 0-500Hz to improve overall performance of signals in each each sector, especially in inclement weather.

In addition, cables themselves are all too often seen to be quite unnecessarily, significantly exposed to movement and induced vibrational microphonics because of the profuse practice of coiling and hanging of excess cable, leaving them to flap about at the mercy of our recently intensified climatic conditions[1]. This practice exacerbates all the identified negative attributes above and should be wholly and instantly proscrbed. The use of Hughes OneLoop - another cable management product designed to preserve bend radii and store excess cable – can wholly eliminate these problems.

Hughes Electronics

are manufacturers of cable interconnects, connections, and cable management products such as One Clamp and One Loop that mitigate the problems discussed in this document.

For more information on products such as OneClamp and OneLoop pease visit our website

www.hugheselectronics.co.uk

References

1. Hughes publication ref here
2. Effect of Vibration on PM and AM noise of Oscillatory and Non-oscillatory Components at 10 GHz A. Hati , C. W. Nelson, and D. A Howe, Member, IEEE National Institute of Standard and Technology Boulder, CO, USA
3. Vibration investigation for telecom structures with smartphone camera: case studies Ying Wang, James Brownjohn, Jose Alfonso Jiménez Capilla, Kaoshan Dai, Wensheng Lu, Ki Young Koo. Journal of Civil Structural Health Monitoring (2021) 11:757–766 https://doi.org/10.1007/s13349-021-00478-9
4. Hughes publication ref here