

DEFORMED BOW-TIE ANTENNA

Torbjörn Olsson, torbjorn.olsson@bofors.se, Mid Sweden University / Bofors Defence
Andrei Koptioug, andrei.koptioug@itm.mh.se, Mid Sweden University
Peter Jonsson, peter.jonsson@mh.se, Mid Sweden University
Johan Sidén, johan.siden@mh.se, Mid Sweden University
Mikael Gulliksson, micke.gulliksson@mkv.mh.se, Mid Sweden University

Abstract

Antennas in some military applications can be expected to suffer from physical damage of the antenna structure itself. Examples are intelligent munitions when rammed into the gun barrel and vehicle mounted conformal antennas harmed by various types of mechanical impact. Another example is extremely low cost antenna applications. A Radio Frequency IDentification (RFID) system consists of a more or less advanced reader and a very simple tag that can be fastened onto a variety of surfaces. The tag incorporates a transceiver and can carry one or more sensing devices and report findings back to the reader. To keep costs down, low-cost standardized antennas will be used even when the tag is deployed in harsh environments.

For the kind of antennas described above, a predictable graceful degradation of performance is appealing. A partial damage of the antenna must not lead to a system breakdown. An essential part of the antenna design must be to ensure robust communication even when the antenna is partially damaged.

What performance can be expected from an antenna when part of its structure has been removed? In this paper this issue is examined for a bow-tie antenna when part of its structure has been removed. The structural deformation has been inflicted by removing stripes of the outer part of one of the antenna arms. The investigation was undertaken by simulations in a commercial Finite Integration (FI) program and by verifying measurements.

Introduction

Even if the Bow-tie antenna is a well-examined structure [1], antenna performance after removal of part of the antenna structure is a new interesting topic in some specific application areas. Damaged antennas have been investigated before for non-destructive bending of antennas [2]. Military equipment is obviously likely to be physically damaged, but also low-cost civilian electronics can suffer physical damage. For low-cost electronics you cannot afford costly protection, which could mean deployment of antennas without additional protection in harsh environments. An example is the extremely low cost applications used in RFID systems. It consists of a more or less advanced reader and a very simple tag that can be fastened onto a variety of surfaces. The tag incorporates a transceiver and can carry one or more sensing devices and report findings back to the reader. To keep costs down, low-cost standardized antennas without additional protection are used even when the tags are deployed in harsh environments. The challenge is to find ways to make the antenna robust, in this sense, at the lowest possible additional cost. The first step is to find out how bad the performance reduction is when cutting of part of the antenna structure.

For the kind of antennas described above, a predictable graceful degradation of performance is appealing. A partial damage of the antenna must not lead to a system breakdown. An essential part of the antenna design must be to ensure robust communication even when the antenna is partially damaged.

For applications where the antenna is randomly oriented in space, a change of directivity could be beneficial or disadvantageous depending on the present orientation, are thus of minor interest for this paper. A typical example is items with RFID-tags in a shopping cart where the primary request is that the tag has a high probability of being detected whatever orientation it has. The same reasoning can be made for other parameters. Therefore the focus in this paper is on the antenna ability as an efficient radiator in terms of impedance mismatch for a damaged bow-tie antenna. The damage is inflicted by removing the outer end of one of the antenna arms. This is somewhat analogous of displacing the antenna feed for a

dipole antenna. For each length reduction the Voltage Standing Wave Ratio (VSWR) and bandwidth is calculated at the original (undamaged antenna) resonance frequency (1:st resonance). This is made in order to illustrate the change experienced by the antenna feed. For a RFID system, constituting a base station and one or more tags, the VSWR affects the “Read zone” [3] which is defined as the volume inside which a base station can communicate with RFID tags.

The antenna length and the flare angle can be used to impedance match Bow-tie antennas and the length to flare angle relation for zero reactance is approximately linear for flare angles 30-90 degrees [1]. This makes it interesting, from a robustness perspective, to investigate whether a Bow-tie antenna with broader flare angle (with more conducting material) is less sensitive to damage than a Bow-tie with a narrow flare angle.

The calculations are made in a FI software suite [4] and additional measurements to verify the simulated results are made.

Simulations and measurements

Three different Bow-tie antenna geometries are considered with flare angle $\alpha = 30, 60$ and 90 degrees respectively. The uniplanar Bow-tie antenna geometry, fed in the middle, is shown in Fig. 1.

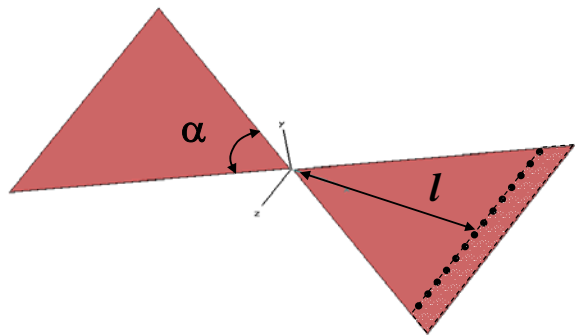


Fig. 1. Bow-tie antenna

The total length of the undamaged antennas used is 262 mm for all antennas. The length was picked (by the same motivation as in ref [1]) as a convenient size to do measurements on and yet not so high as to affect the accuracy. The antenna thickness and feed gap used for the simulations are 0.12 mm and 2 mm respectively. The length l of one of the antenna arms is varied to simulate a damaged antenna with the outermost part of its structure removed. The calculation starts with an undamaged antenna with two fully symmetric antenna arms and is continued for shorter and shorter l .

The simulations are made under the following assumptions:

- The antenna material is regarded as Perfect Conductor (PEC)
- The antenna is located in free space
- No special consideration is taken in the simulations to model the feed arrangements used for the measurements

The derived parameters are:

- VSWR at the undamaged antenna’s resonance frequency,
- Bandwidth at the undamaged antenna resonance frequency
- Resonance frequency for the various shortening of one of the antenna arms

The antenna measurements are done for different antenna shortening of one of the antenna arms to verify the simulation results. The antennas are made of thin metal (iron) sheets (0.12 mm thickness) on cardboard substrate.

Results

Fig. 2. shows VSWR at the undamaged antenna's resonance frequency versus percent of the original antenna arm length. The curves show that flare angle has no real impact on the performance decline. All antennas pass the VSWR = 2 level at about 86 % remaining arm length. Measured VSWR for some shortening of one of the antenna arms are also plotted with reasonable resemblance with the simulated results.

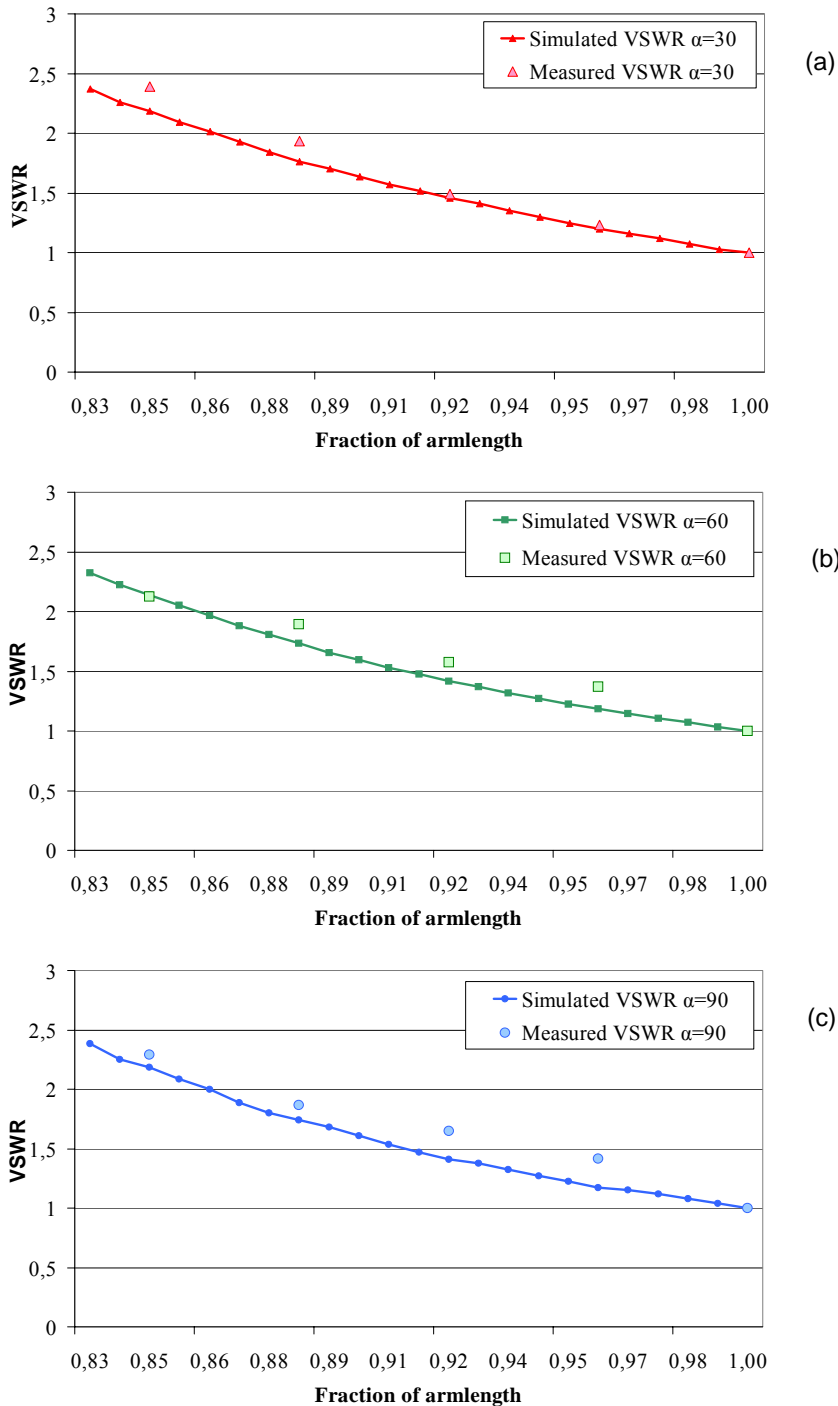


Fig. 2. VSWR as a function of the damaged arm length at the undamaged antenna's resonance frequency for (a) 30, (b) 60 and (c) 90 degrees flare angle

The bandwidth (BW) definition used in this paper is defined in Fig. 3. This bandwidth definition gives a measure on how much less bandwidth a tuned antenna experience due to the inflicted damage. This is of course dependent upon the type of modulation method used. The used criterion for acceptable performance is VSWR less than 2 and this gives a frequency interval Δ for the undamaged antenna. The frequency interval δ , for the damaged antenna, is defined by the less than VSWR=2 criteria and that it must be a part of the Δ interval.

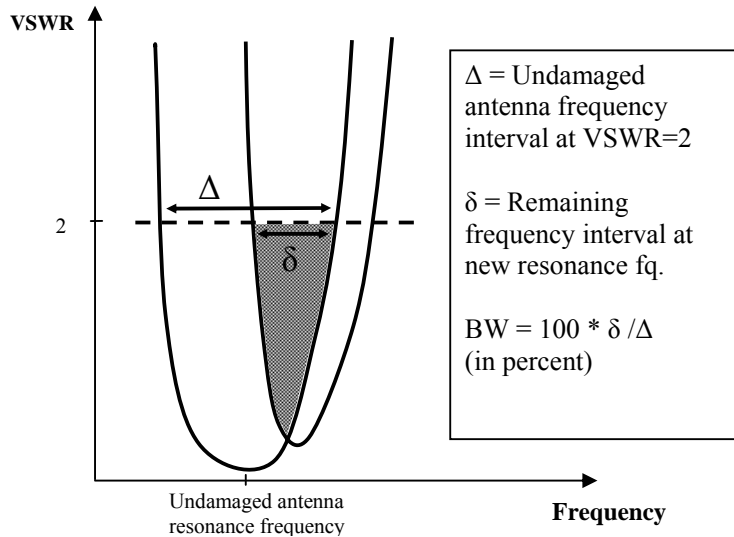


Fig. 3. Bandwidth definition

In Fig. 4. the Bandwidth is plotted versus antenna arm length. The slope is about linear, and no bandwidth remains when approximately 72% of the antenna arm length remains and the decline seems to be roughly independent of flare angle for the Bow-tie antennas.

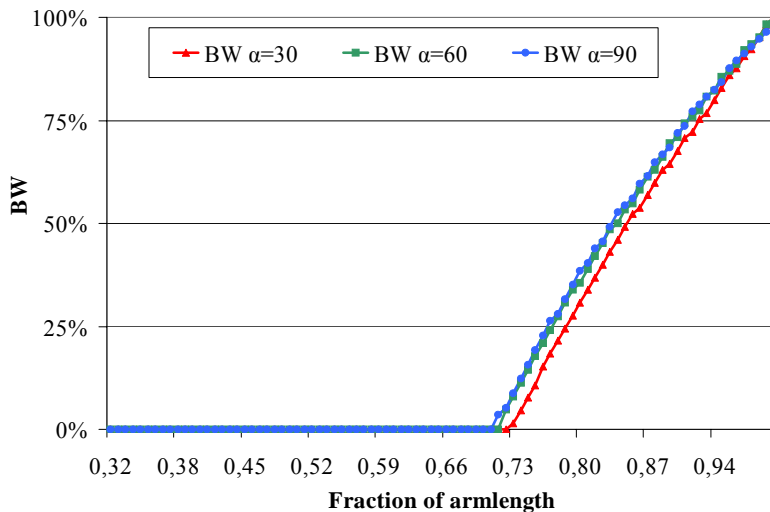


Fig. 4. Bandwidth as a function of the damaged arm length at undamaged antenna's resonance frequency

The graphs in Fig. 5. shows the resonance frequency for each antenna arm length. The slow rise in resonance frequency when shortening one of the antenna arms is considered to be mainly due to the shortening of the structures resonance lengths. Measured resonance frequencies are also plotted with reasonable resemblance with the simulated results.

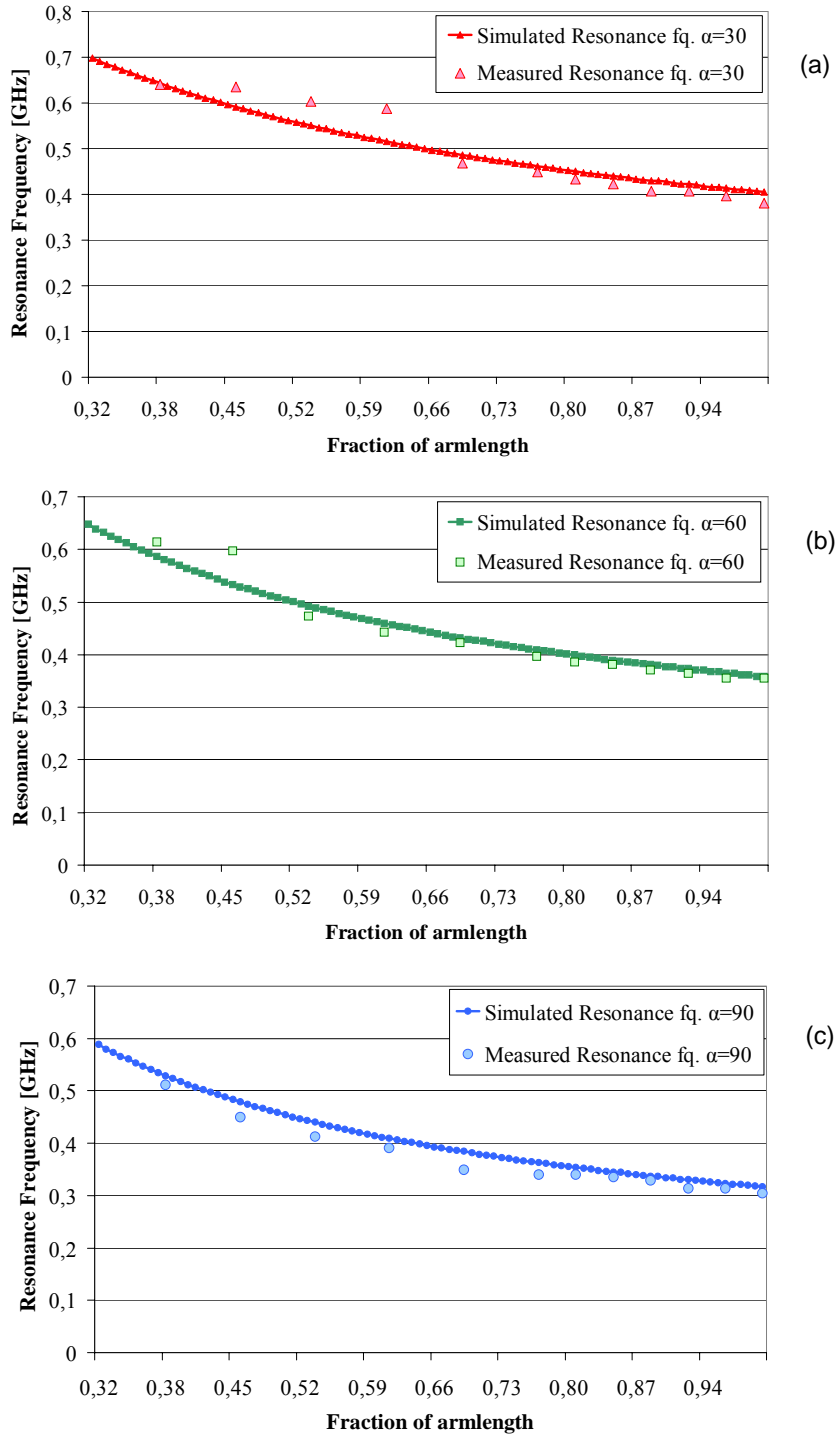


Fig. 5. Resonance frequency as a function the damaged arm length for (a) 30, (b) 60 and (c) 90 degrees flare angle

Discussion

The quality of the input impedance match between antenna and the feed is described by the VSWR. The results from the simulations indicate that the loss in impedance match is approximately linear up to the VSWR=2 level. The VSWR=2 level is broken when about 86% of the arm length remains for all three flare angles.

The bandwidth experienced by the tuned system drops approximately linearly to zero when the damage has reached about 72% of the antenna arm length for all three flare angles.

The resonance frequency change increases, as expected, for shorter antenna lengths approximately equally for the three different flare angles investigated

From the results above a conclusion is that a wider flare angle does not mean that the antenna will be more robust to the type of damage investigated in this paper. The behaviour is approximately equivalent for the three flare angles considered.

When designing a low cost Bow-tie antenna to be robust against the kind of damage investigated in this paper, an antenna with a smaller flare angle is the choice to keep the amount of conducting material as small as possible. This is due to the cost savings that can be made by using smaller amounts of expensive conducting materials (metals, conducting inks etc.) yet possessing virtually the same robustness as an antenna with a wider flare angle.

Another conclusion is that it is possible to place a Bow-tie antenna close to the substrate border even if it is likely to suffer from some kind of limited physical damage there. The results presented above shows that a Bow-tie antenna could handle minor damage at the end of one of its arms, still maintaining satisfactory performance.

References

1. *Experimentally determined radiation characteristics of conical and triangular antennas*; George H. Brown, O. M. Woodward Jr.; *RCA Review*, December 1952, Vol. 13, No 4, Page(s): 425 -452
2. *Performance degradation of RFID system due to the distortion in RFID tag antenna*; J. Sidén, P. Jonsson, T. Olsson, G. Wang; *Microwave and Telecommunication Technology*, 2001. *CriMiCo 2001. 11th International Conference on*, 2001 Page(s): 371 -373
3. *On the read zone analysis of radio frequency identification systems with transponders oriented in arbitrary directions*; K.V.S. Rao, Dah-Weih Duan, Harley Heinrich; *Microwave Conference, 1999 Asia Pacific*, Volume: 3, 1999 Page(s): 758 -761 vol.3
4. *CST; Microwave Studio*; <http://www.cst.de>