

Experimental Investigation of the Performance of Two-Element Helical Antenna Array for Television and Mobile Phone Networks Operating at 400-900 MHz Band

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Abstract: In this study, the design, construction and experimental investigation of the performance of two-element helical antenna array for television and mobile phone networks operating at 400-900 MHz band are reported. The Chang Puak online simulator was employed to carry out the geometrical structural design, using 4 mm diameter copper pipe for the helical elements constructions, flat plate aluminium as the reflector, 110 mm diameter PVC pipe and steel plates as supports for the helical elements. The spacing of the helical elements of the array corresponds to the wavelengths of the upper, middle and lower frequencies of the desired frequency band. The experimental measurements of the frequency responses and radiation patterns of the proposed antenna array were carried out to analyze the performances of the antenna within the frequency band under consideration while varying the spacing between the helical elements. The results obtained show that practical Butterworth (flat) frequency responses were observed for the proposed antenna at the desired frequency band for all spacing under consideration. Also, the results of measured radiation patterns obtained at all resonant frequency within the desired frequency band for all spacing under consideration show that the proposed 2-element helical antenna array is highly bi-directional type. The antenna can be employed as a mobile phone signal booster's antenna and also as a Very High Frequency/Ultra High Frequency (VHF/UHF) television reception antenna.

Key words: Design, helical antenna array, experimental investigation, frequency response, radiation pattern, mobile phone repeater

INTRODUCTION

The advent of the Information Communication Technology (ICT) in recent time has increased the usage of mobile phone repeater or signal booster particularly in the environments regarded as shadowed areas (areas behind high terrain or man-made structures) for mobile phone communication network links. Mobile phone repeater is usually a type of Bi-Directional Amplifier (BDA) which rebroadcast cellular signals inside building. The systems usually use an external, cross or circularly polarized and directional antenna to collect the best cellular signal which is then transmitted to an amplifier unit which amplifies the signal and retransmits it locally, also through an antenna.

An antenna (or aerial) is an electronic device designed to transmit or receive electromagnetic waves in an efficient manner. The market for mobile phone repeaters or signal boosters is expected to grow rapidly

over the coming years because of numerous advantages of the mobile phone usage particularly in this era of ICT (Wong, 2005; TX RX Systems Note, 2009; Wikipedia, 2009). As mentioned before, one of the important features of the repeater or signal booster is the antenna which has high directional property over wide bandwidth. If this demand must be met, the research into the reconfiguration of antennas in order to improve their performances should be intensified (Nakano *et al.*, 1992; Alade *et al.*, 2000; Ajay, 2004; Scott and Frobenius, 2008; Alade and Akande, 2010). In this study, the design, construction and experimental investigation of the performance (in terms of the frequency response and radiation pattern) of the 2-helical element antenna array for operation at 400-900 MHz band are presented. The proposed antenna has demonstrated high bi-directional radiation pattern property at the wide frequency band under consideration which make it suitable as mobile phone signal booster's antenna and VHF/UHF television reception antenna.

MATERIALS AND METHODS

The geometrical structural design: The proposed 2-element helical antenna array is designed using Chang Puak online simulator suitable for axial mode helix antenna (Fig. 1).

The inputs data are centre frequency and number of turns of helix for the design. The design centre frequency, f_c is given as:

$$f_c = \frac{f_u + f_l}{2} \tag{1}$$

Where:

- f_u = The upper frequency (900 MHz)
- f_l = The lower frequency (400 MHz) of the design frequency band of the proposed 2-element helical antenna array

The centre frequency and the number of turns were simulated using Chang Puank online simulator available at www.changpuak.ch/electronics/calc12b.html (Puak, 2008). The following results were obtained:

| | |
|------------------------------------|---------------|
| Design centre frequency (f_c): | 650 MHz |
| Number of turns: | 12 |
| Turn spacing: | 461.538 mmths |
| Gain : | 16.571 dB |
| Impedance of Antenna (R): | 140 Ω |
| Length of helix L_2 : | 1384.62 mm |
| Helix diameters d_2 : | 146.912 mm |
| Disc diameter d_3 : | 507.69 mm |

Construction details of the proposed 2-element helical antenna array:

The wooden groove of the same diameter as the helix antenna element was attached to a lathe machine and the copper conducting wire of internal diameter 4 mm was wound round the wooden groove in form of a screw thread forming a helix antenna with the aid of a lathe machine. The wooden groove was removed and replace with PVC pipe of the same diameter as the helix and mounted on the flat plate of aluminium with tighten bolts. The flat plate of aluminium serves as a reflector while the PVC pipe serves as a supporting structure for the helix element (Fig. 2). In order to provide a good matching with 75 ohms coaxial cable transmission line, the input impedance of the helix was reduced to near the value of coaxial cable by properly design the first $\frac{1}{4}$ turn of the helix which is next to the feed with a strip conductor of width 12.5 mm. The helix antenna was connected to the centre conductor of a coaxial transmission line at the feed point.

Array elements spacing of the proposed helical antenna array:

The spacing between the elements of the proposed 2-element helical antenna array in this study, corresponds to the wavelengths (λ) of the upper frequency, middle frequency and lower frequency of the frequency band under consideration. The spacing technique adopted for the experimental investigation of the performance of the proposed antenna array is based on the analytical electromagnetic relationship between the design frequency (f) and the speed (c) of electromagnetic waves:

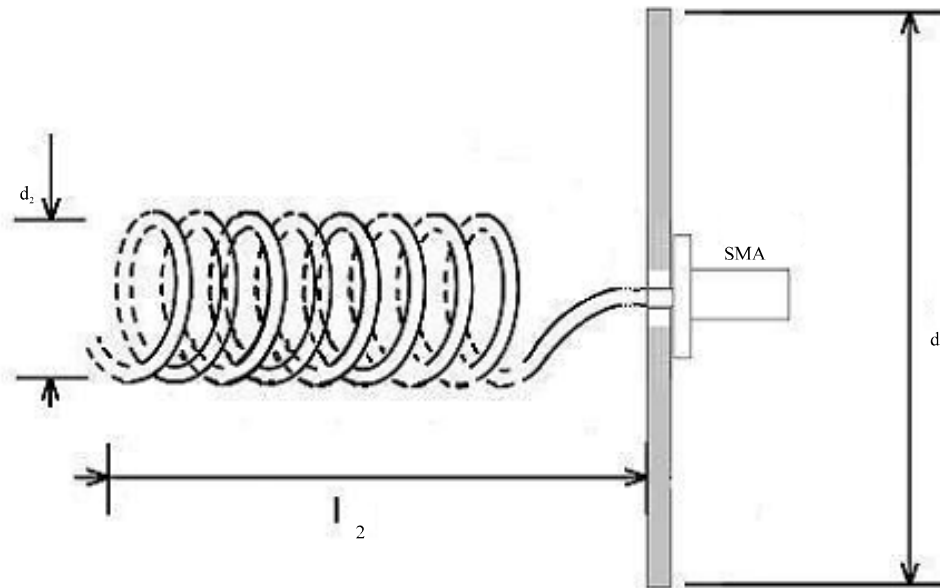


Fig. 1: The helical antenna geometrical configuration design (Puak, 2008)

$$c = f \lambda \quad (2)$$

- For upper frequency: $f_U = 900\text{MHz}$, $\lambda_U = S1 = 33.33$ cm
- For mid frequency: $f_M = 650\text{MHz}$, $\lambda_M = S2 = 46.15$ cm and $S3 = \lambda_M/2 = 23.075$ cm
- For lower frequency: $f_L = 400\text{MHz}$, $\lambda_L = S4 = 75$ cm

The experimental measurements: The frequency responses and radiation patterns of the proposed helical antenna array were measured and used to analyze the performance of the antenna at 400-900 MHz band. One of the helical elements was fixed at zero position while varying the position of the second helical element at various spacing: S1, S2, S3 and S4 for the frequencies within the desired band.

The experiment was deliberately conducted outdoor (Fig. 3) because the proposed antenna constructed is meant to be used outdoor even in the presence of environmental noise as the repeater amplifier antenna for mobile phone and television networks.

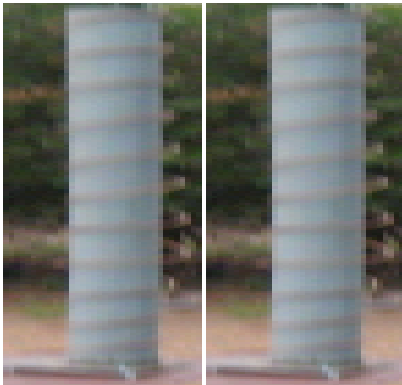


Fig. 2: Structure of the constructed helical antenna elements



Fig. 3: The open-area experimental setup for the proposed helical antenna array

The apparatus and equipments employed for the experimental measurements are:

- Spectrum analyzer GPS810
- Hp Laptop computer (PSLB8E)
- Two helical antennas
- Antenna mast (Rotary type)
- 650 VA Power Inverter
- 200 AH dry cell battery
- Protractor
- Table

RESULTS AND DISCUSSION

In this study, experimental investigations of the performance of the 2-element helical antenna array at 400-900 MHz band for use as mobile phone signal booster's antenna or as VHF/UHF television reception antenna have been reported.

Figure 4 shows the results of the measured signal strengths received by the antenna as the resonant frequency is varied from 400-900 MHz for different spacing between the elements of the proposed 2-element helical antenna array. Ideal practical Butterworth (flat) frequency responses were observed for the proposed antenna at the desired frequency band for all spacing under consideration.

The signal strength received is at the maximum when the spacing between the elements of the proposed antenna is S2 (S2 is the wavelength of the middle frequency of the desired frequency band). Also, the results of measured radiation patterns obtained at all resonant frequency within the desired frequency band for

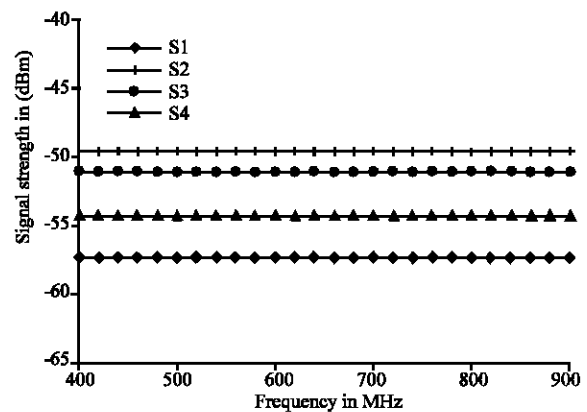


Fig. 4: The plot of the received signal strength versus the frequency for different spacings between the elements of the proposed Helical antenna array

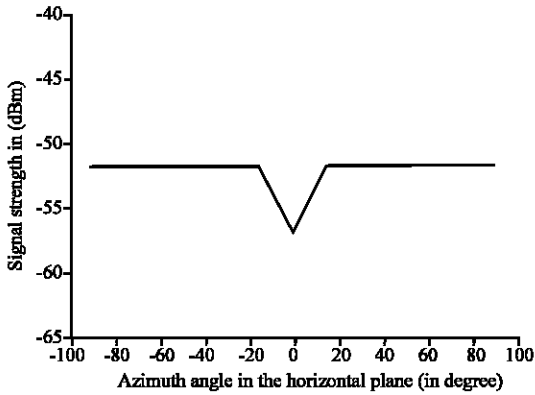


Fig. 5: Radiation patten in the horizontal plane at frequency of 650 MHz when the specing between the elements of the proposed helical antenna array is set at S1

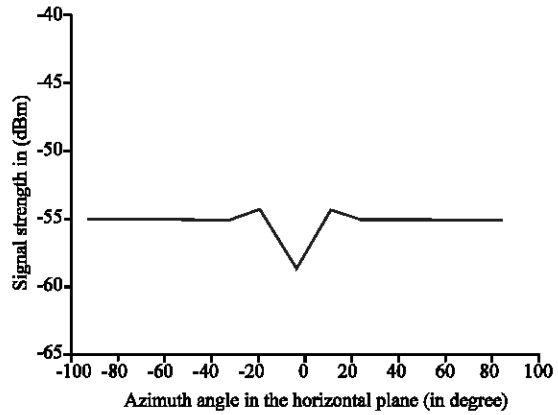


Fig. 8: Radiation patten in the horizontal plane at frequency of 650 MHz when the specing between the elements of the proposed helical antenna array is set at S4

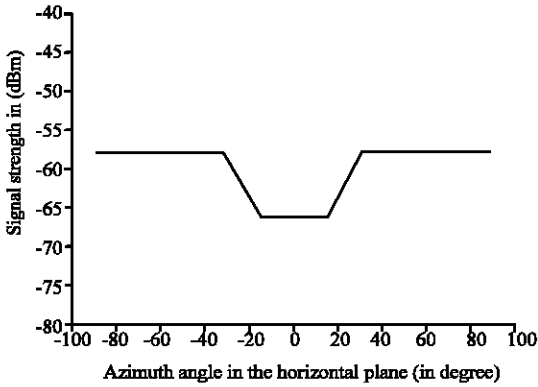


Fig. 6: Radiation patten in the horizontal plane at frequency of 650 MHz when the specing between the elements of the proposed helical antenna array is set at S2

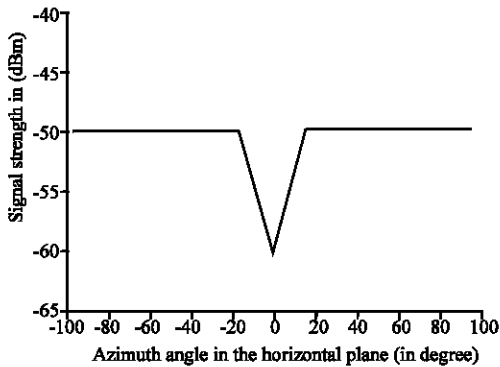


Fig. 7: Radiation patten in the horizontal plane at frequency of 650 MHz when the specing between the elements of the proposed helical antenna array is set at S3

all spacing under consideration show that the proposed 2-element helical antenna array is highly bi-directional type. Figure 5-8 show some examples of the measured radiation patterns of the proposed antenna for different spacing between its elements at 650 MHz.

CONCLUSION

The results of the measured frequency responses and radiation patterns have shown that the propose 2-element helical antenna array is a bi-directional antenna in agreement with the results of previous researches done by Nakano *et al.* (1992), Kraus *et al.* (2002) and Balanis (2005). The proposed antenna has demonstrated high performance ability within the desired wide bandwidth. The antenna can be employed as the repeater's or signal booster's antenna to pull down the mobile and television networks signals particularly in the extended frequency range of 400-900 MHz as much as possible from the nearest accessible mobile phone network links or television Stations to provide coverage (good signal receptions) for the locations that are regarded as shadowed areas or far from the signal transmission stations.

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