Miniaturized Dipole Antenna Development for Low Frequency Ground Penetrating Radar (GPR) System

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Abstract

A miniaturized symmetrical dipole antenna with extra radiating arms is proposed for low frequency operation (100 MHz) in ground penetrating radar applications to achieve high depth penetration at low resolution. The dipole antenna design is of total dimension 66.5 cm × 22 cm. A parametric study of antenna performance is performed via simulation with Agilent Advanced Digital System software which indicates an optimum length of 15 cm for the extra arm with a gap of 5 cm between the dipole arm and extra arm. The results are validated experimentally in room conditions with a prototype antenna fabricated on 1.6 mm thick FRA substrate, copper layer thickness of 17 µm. The antenna operating at a centre frequency of 104 MHz and bandwidth of 8 MHz for VSWR ≤ 2 achieves a 55% reduction in length compared to a conventional dipole operating at 100 MHz while delivering typical dipole radiation pattern with directivity gain of 2.06 dBi.

Introduction

- A miniaturized symmetrical dipole antenna with extra radiating arms is proposed for low frequency operation (100 MHz).
- Physical size and gain of antennas are determined by the operating frequency.
- Small antennas offer compact system dimension.
- Small antennas have a low gain at lower frequencies and larger antennas are required to operate at lower frequencies.

Background

- Application of GPR in low frequency region.
- GPR frequency ranges from 10 MHz – 2 GHz depending on depth penetration and resolution.
- Higher frequency offers low depth penetration and high signal attenuation problem [1].
- Low frequency delivers high depth penetration at low resolution.

Frequency, MHz	2000	900	500	300
Resolution, m	0.04 - 0.08	0.2	0.5	1.0
Depth, m	1.5 - 2	3 - 5	7 - 10	7 - 10
Blind Zone, m	0.06	0.1 – 0.2	0.25 – 0.5	0.5 – 1.0

Table 1: Performance of GPR with different frequencies [2].

Figure 1: GPR scanning with 100 MHz unshielded and shielded dipole antenna.

Dipole Antenna Miniaturization

- 31% length reduction is recorded for 500 MHz bow-tie antenna in [3].
- 26% reduction is recorded for 700 MHz folded dipole antenna in [4].
- Most of the miniaturization techniques found in literature are for high frequency antennas.

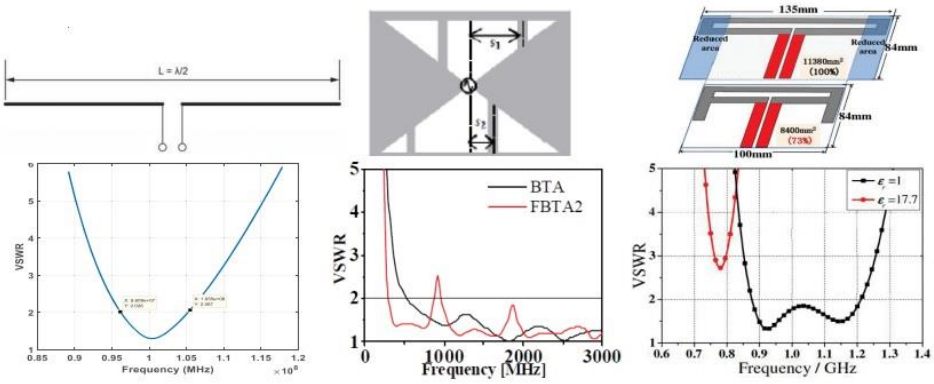

Figure 2: VSWR characteristics of conventional dipole antenna, antenna proposed in [3] and [4].

Proposed Antenna Design

- A dipole antenna with extra radiating arms is proposed.
- Total antenna dimension is 66.5 cm × 22 cm.
- Effect of different length of extra arms, *l* and the gap between the dipole arm and extra arm, g are studied in parametric study.
- Agilent Advanced Digital System (ADS) software suite is used for simulations.

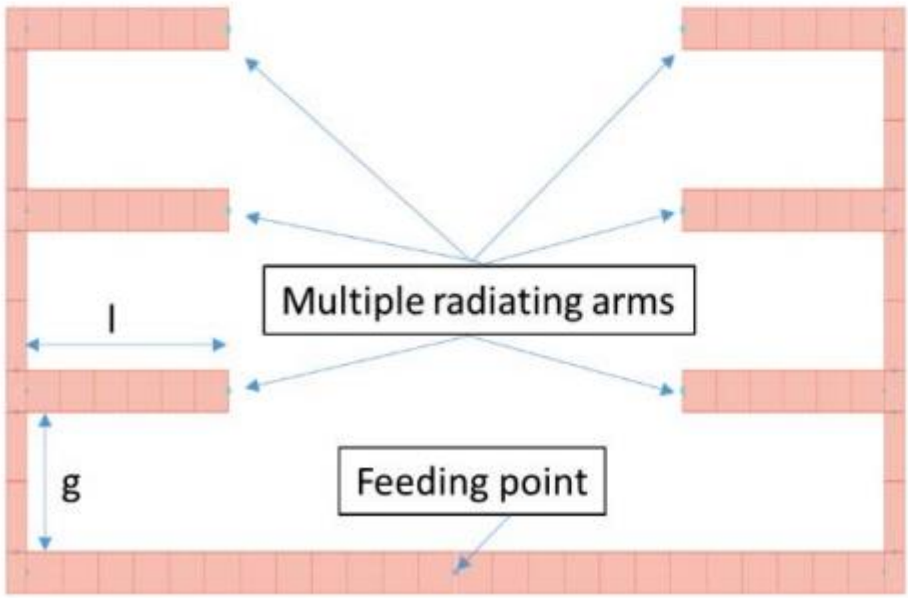

Figure 3: Proposed miniaturized 100 MHz dipole antenna.

Parametric Study of Antenna Performance

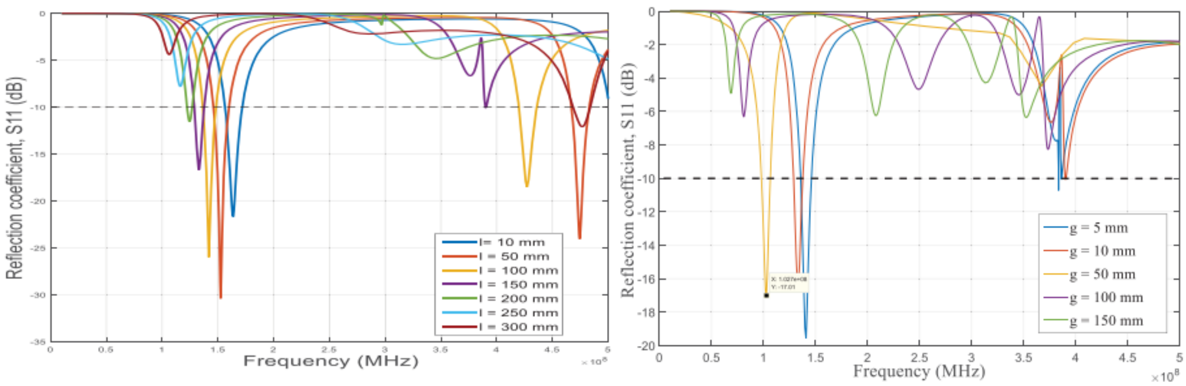

Figure 4: Reflection coefficient, S11 values for different *l* and *g*.

Optimum values: At *l* = 15 cm and *g* = 5 cm, centre frequency = 102 MHz

Antenna Performance

Figure 5: Current density distribution on the proposed antenna compared to a conventional dipole.

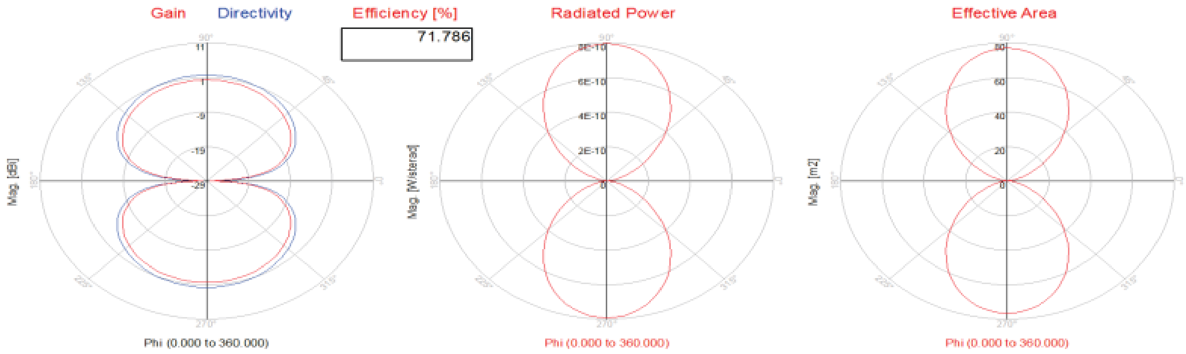

Figure 6: 2D radiation pattern of the proposed antenna.

Experimental Setup

- Prototype antenna fabricated on 1.6 mm thick FR4 substrate.
- Copper layer thickness was 17 µm.
- Agilent 4395A network analyser was used for a frequency sweep of 0 – 500 MHz.
- Experiment was carried out in room conditions.

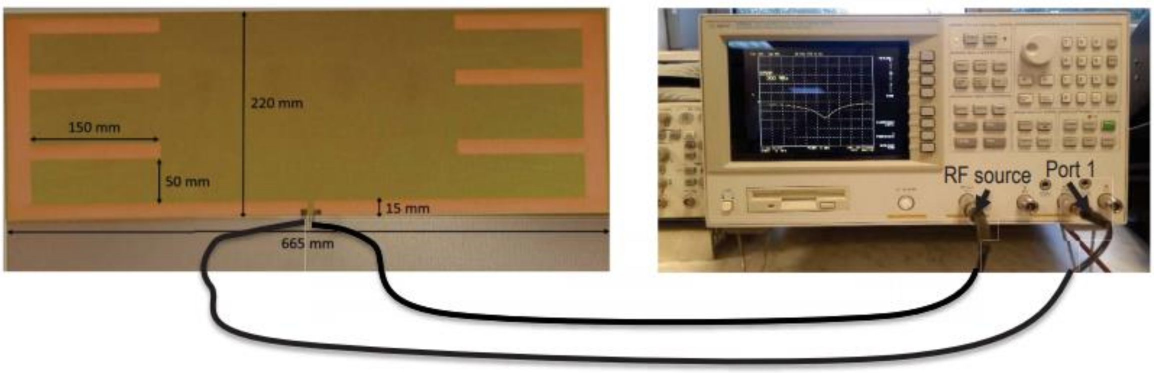

Figure 7: Prototype antenna and experimental setup block diagram.

Results

- Antenna centre frequency is 104 MHz.
- Bandwidth is 8 MHz for VSWR ≤ 2.

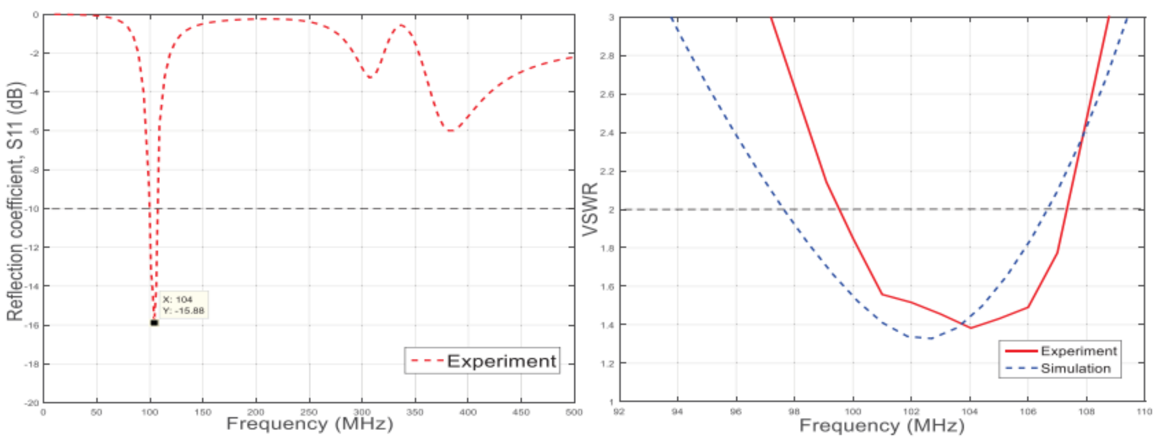

Figure 8: S11 and VSWR characteristic comparison of measured and simulated values.

Conclusions

Adding extra radiating arms on a dipole antenna can significantly reduce antenna size.

Laboratory prototype antenna achieved a 55% reduction in length compared to a conventional dipole of 100 MHz.

The antenna delivers typical dipole radiation pattern delivers with directivity gain of 2.06 dBi.

Proposed antenna shows significant improvement compared to [5], [6].

References

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