FMCW Phased Array Radar for Snow Avalanche Imaging

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Introduction

Avalanche hazard mapping has historically relied on observation of occurrences and run out distances. Therefore, rare and possibly extreme, avalanches are missed because they are never observed. In UCL we have developed an advanced FMCW phased array radar to model avalanche dynamics which can lead to other complementary methods of predicting avalanche occurrence.

Developed FMCW Phased Array Radar

- FMCW radar applies frequency modulation to the continuous wave carrier signal to allow range measurement.
- The predictable changing frequency over time allows the target range to be determined.
  - The 5.3 GHz FMCW radar is capable of measuring range and velocity of dense regions of snow avalanche
- FMCW radar consists of 8 elements sparsely sampled phased array receiver and a single transmitter
  - Phased array enables the radar to image the avalanche in 2-D, in terms of range and cross range resolution

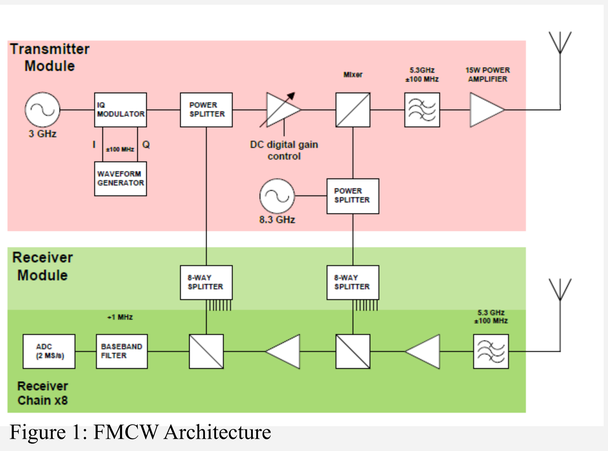


Figure 1: FMCW Architecture

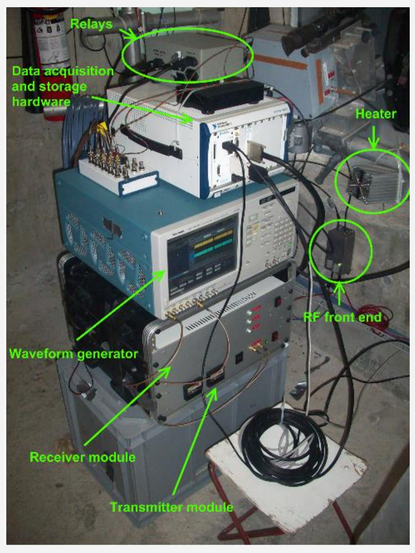


Figure2: Developed radar

FMCW Radar Specifications	
Operating Frequency	5.3 GHz
Waveform Bandwidth	200 MHz
Phased Array Beam width	0.6°
Transmit power	15 W
Range resolution	1 m

System improvement areas

- PCB mounted design can be used for cohering the data from the receivers.
- To satisfy SNR requirements for detection in cross range, lowering of the array side lobes is required

Phased array antenna upgrade

- Increasing the number of elements from 8 to 16
  - Fully sampled phased array antenna over the narrow field of view ±14°
  - 16 sub-arrays of 4 elements
  - Wider antenna aperture
- Avoid aliasing and supressing grating lobes
  - Sub-array elements
    - Overlapping sub-array elements

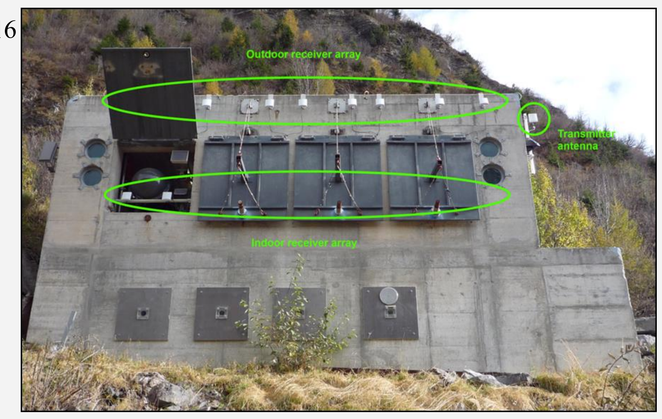
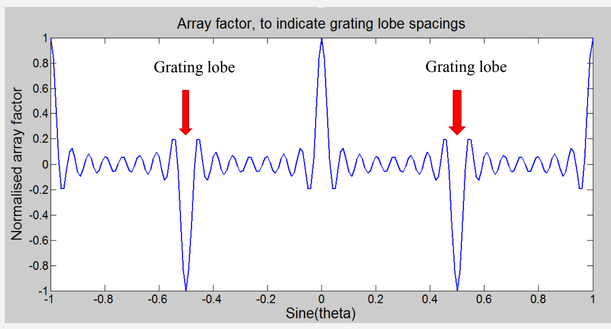


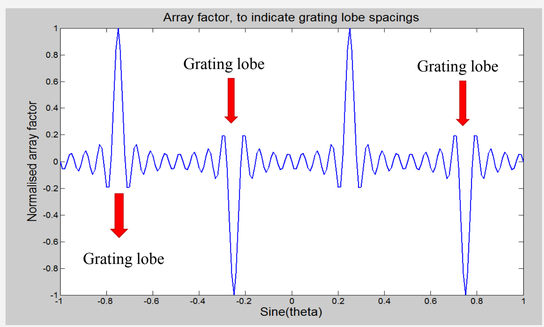
Figure 4: Bunker

Antenna inter-element spacing

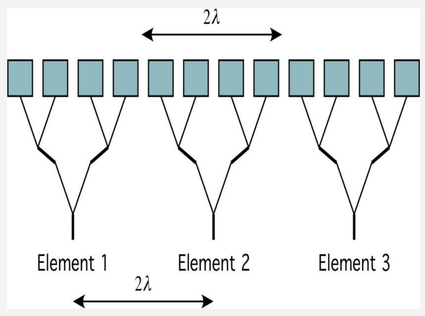
2 λ Inter-element spacing ➔ ± 14° unambiguous angular coverage

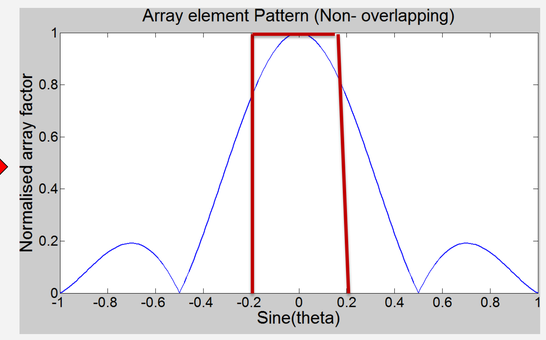
Signals at the edge of field of view +14° SinΘ = 0.25



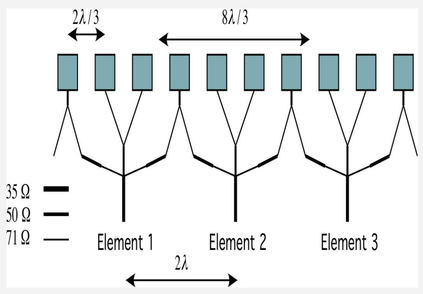


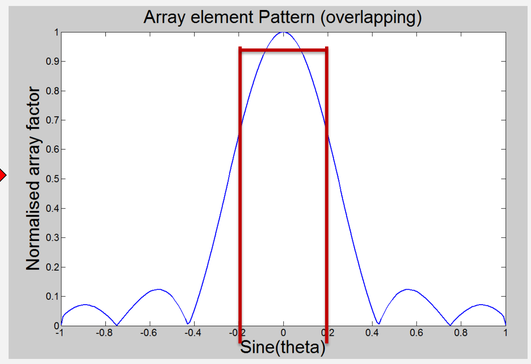
Sub-arraying elements





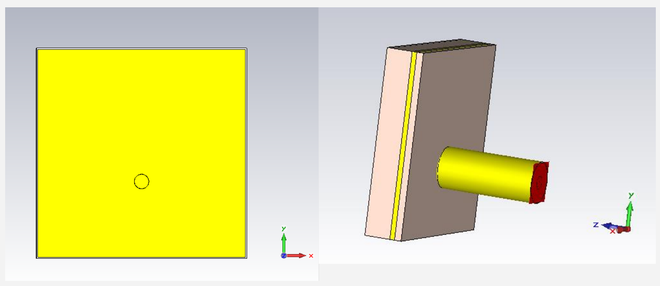
Overlapping Sub-array

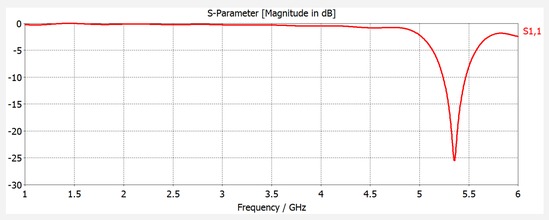




Phased Array antenna Design

Single Patch antenna operating at 5.3 GHz with 230 MHz Bandwidth

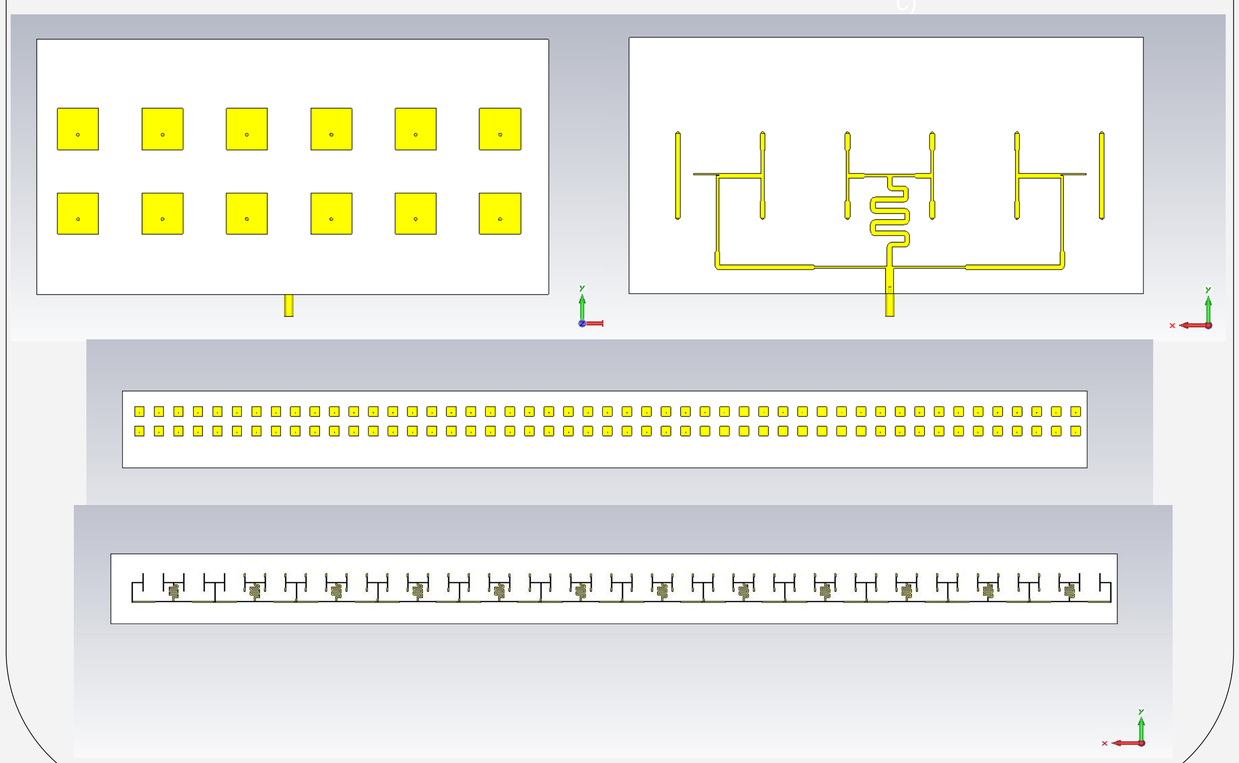




S11, dB

Single sub-array of patches

Wilkinson feed network



Conclusion

- Upgrading the phased array antenna
- Optimizing the antenna to obtain the desired specifications
- Redesigning the FMCW radar system based on the previous experiences

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