Comparison Study of Multi-Beams Radar under Different Radar Cross Section and Different Transmitting Frequency

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Abstract: In this paper a comparison study is presented in order to evaluate the Simultaneous Multi - Beams radar under different radar cross section and different transmitting frequencies in order to evaluate the new radar performance under such complex environment. The results show that increasing the transmitting frequency will decrease the radar coverage and increasing the radar cross section will increase the radar coverage. Under such conditions the Simultaneous Multi–Beams radar offers good maneuverability and performance because it will choose the best type of beam according to the radar type, radar cross section, and target height and frequency diversity. Also it is concluded that the planner array will provide good beam forming and beam shaping techniques and it is possible to implement and construct a smart DSP processor which will choose the appropriate beam according to the target plat form and detection scenario for the new technology in addition to save time and cost.

Keywords: Component, Beam-Forming, Radar Coverage, Smart Processor

1. Introduction

The radiation pattern of an antenna is generally the basic requirement since it determines the spatial distribution of the radiated energy (Peyton, 1998; Rohan, 1981; Henry, 1961). The array antenna is comprised of a number of identical radiating elements in a regular arrangement (David, 1998), that together form a radio beam; it is even possible to produce and multiple the truly simultaneous beams. When the array elements are located in a plane, it is said to be a planar array (Warren & Gary, 2012; Thomas, 1994; Xing, 2001).

2. Theoretical Principles

2.1 Arrays

An array is a composite antenna formed from two or more basic radiators, to produce a directional radiation pattern. Each radiator is denoted as an element. The elements forming an array could be dipoles, dish reflectors, slots in a wave guide, or any other type of radiator (Qaysar, 2010). The small radiators act together with some overall area to produce the effect of an antenna which has the overall area. The mechanical problems associated with a single large antenna are traded for the electrical problems of feeding several small antennas. Array antennas were introduced for use in the radar systems, and satellite communication systems.

2.2 Planar Array Antenna

The electric field at a far field observation point was defined by (θ, Φ) (Bassem, 2000);

$$E_x(\theta,\phi)=\sum_{n=1}^{N} e^{j(n-1)kd_x \sin\theta\cos\phi} \tag{1}$$

where d_x is the element spacing along the x

The rectangular array's one-way intensity pattern is then equal to the product of the individual patterns. More precisely (Bassem, 2000);

$$E(\theta,\phi)=\left|\frac{\sin((Nkd_x\sin\theta\cos\phi)/2)}{\sin((kd_x\sin\theta\cos\phi)/2)}\right| * \left|\frac{\sin((Nkd_y\sin\theta\sin\phi)/2)}{\sin((kd_y\sin\theta\sin\phi)/2)}\right| \tag{2}$$

The radar equation shows the inverse proportionally of the square root of transmitting frequency with the maximum range that follows:

$$\mathrm{R}_{\max}=\left[\frac{\mathrm{P}_t G^2\lambda^2\sigma}{(4\pi)^3 S_{\min}}\right]^{1/4} \tag{3}$$

where:

P_t : transmitted power (watts),

G: antenna gain (dB),

λ: wavelength (m)

σ: radar cross section(RCS) (m^2),

S_{min}: minimum detectable signal (watts)

The maximum range is proportional to the 4th root of the RCS σ, if we assume that all other parameters are constant, and is given by (Constantine, 2005);

$$\mathrm{R}_{\max}\ \alpha\ {}^{1/4}\!\sqrt{\sigma} \tag{4}$$

Also the relation between the maximum range and the transmitting frequency, if we assume all other parameters are constant, is given by;

$$R_{\max} \propto \frac{1}{\sqrt{f}}, \tag{5}$$

It means that by increasing the transmitting frequency, the maximum range is decreased accordingly. The increasing of transmitting frequency will increase the atmospheric attenuation due to this equation (SELEX, 2010);

$$\alpha_{dB} = K_1 . P \tag{6}$$

Where P is the perception rate mm/h and K_1 is a function of the wavelength from which it may be expressed analytically as (Kaiser, 1988);

$$K_1 = 0.00274\,\lambda 2 - 0.042408\,\lambda + 0.149679 \tag{7}$$

in which λ is the wavelength in cm.

3. Simulation of Radar Coverage

The software package used in the present work is C++ and Matlab programming languages and modified to construct the simultaneous Multi Beams radar coverage. Also the new radar performance is tested and examined for different RCS and different transmitting frequencies. The probability of detection (P_d) is taken to be 80% and the probability of false alarm (Pf.a) is taken to be 10^{-6} for both conditions. A computer simulation with C++ programming is used in the present paper; beam shaping technique is used in order to shape the coverage to cosecant coverage, Pencil, Fan, Transmitte and intermediate beams according to the radar platforms and radar type and function.

4. Results of Beam Shaping Techniques

The simulation package is used to create 4 different coverage of the 2D search radar as explained before, which are: Intermediate, Fan, Pencil and TX beams. For this study, the outputs of beam forming network for this radar are examined for different radar cross sections and different transmitting frequencies.

5. Results of Beam Shaping Techniques

The same package is modified in order to study the RCS effects on different beam coverage in addition to changing the transmitting frequency from 900 MHz to 1300 MHz for the same RCS of 2 s.q.m .Two RCS parameters are used 2 s.q.m and 5 s.q.m.

5.1.1. Different Radar Cross Section

1. 2 m^2 RCS: In this case, the radar cross section is taken to be simulated for small size of target which is 2 m^2. The transmitting frequency is 900 MHz, the P_d is 80% and the P_{fa} is 10^{-6}. Figures 1, 2, 3, 4 show the Intermediate, Fan, Pencil and Transmit Beams respectively when the RCS = 2 s.q.m.

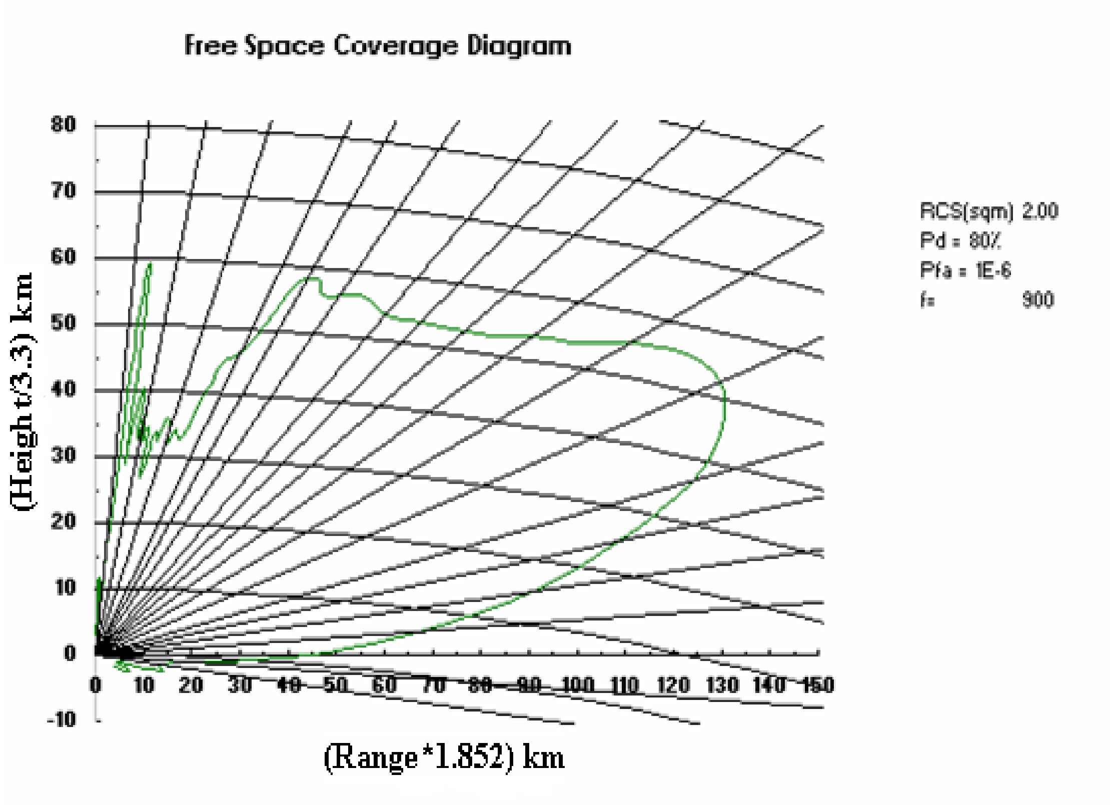

Figure 1: Intermediate Beam Coverage for RCS = 2 s.q.m, f = 900MHz

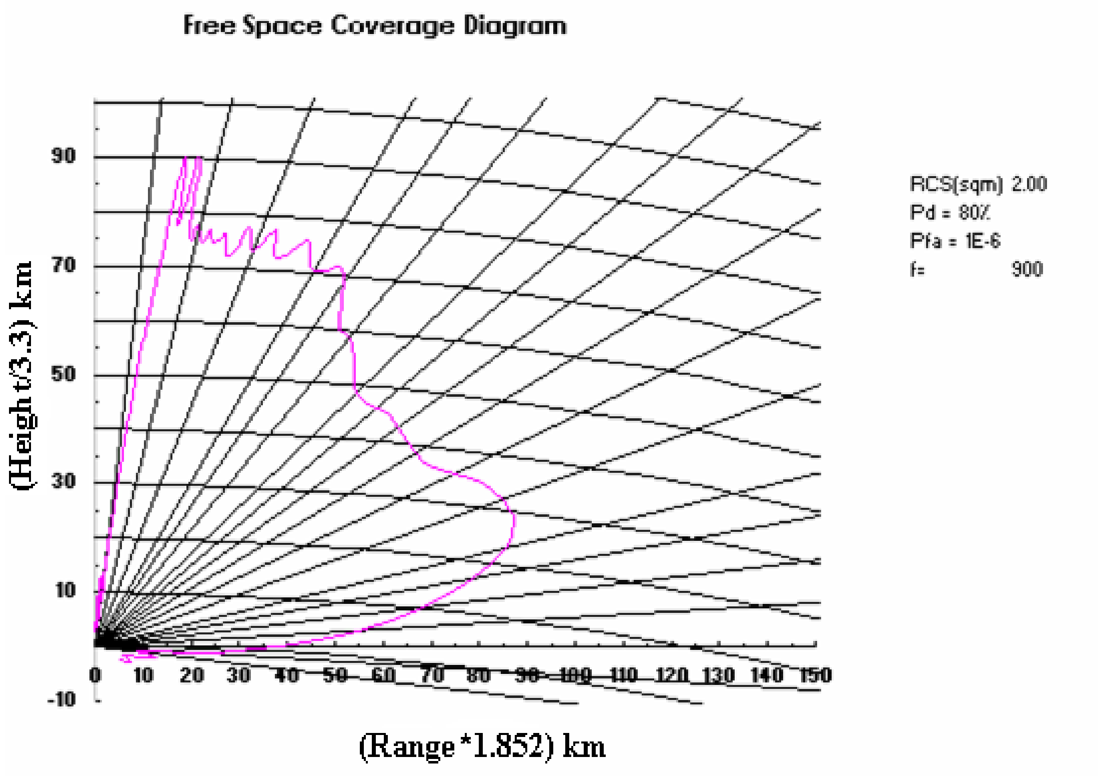

Figure 2: Fan Beam Coverage for RCS = 2 s.q.m, f= 900 MHz

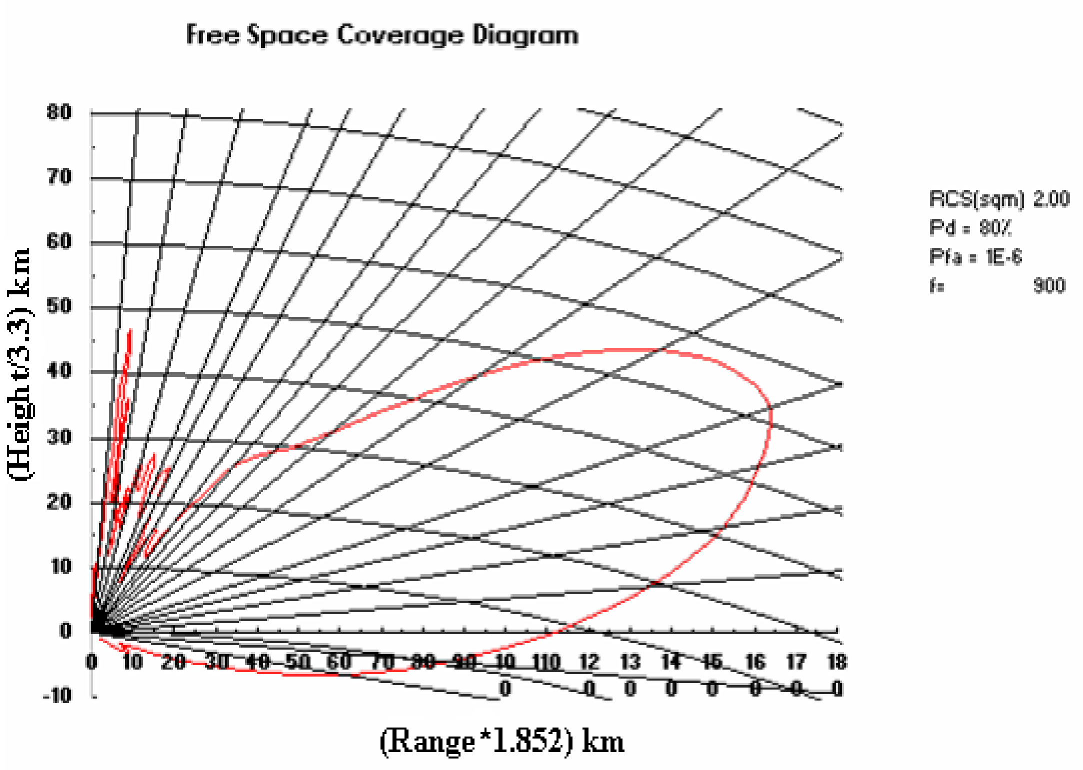

Figure 3: Pencil Beam coverage for RCS = 2 s.q.m, f = 900MHz

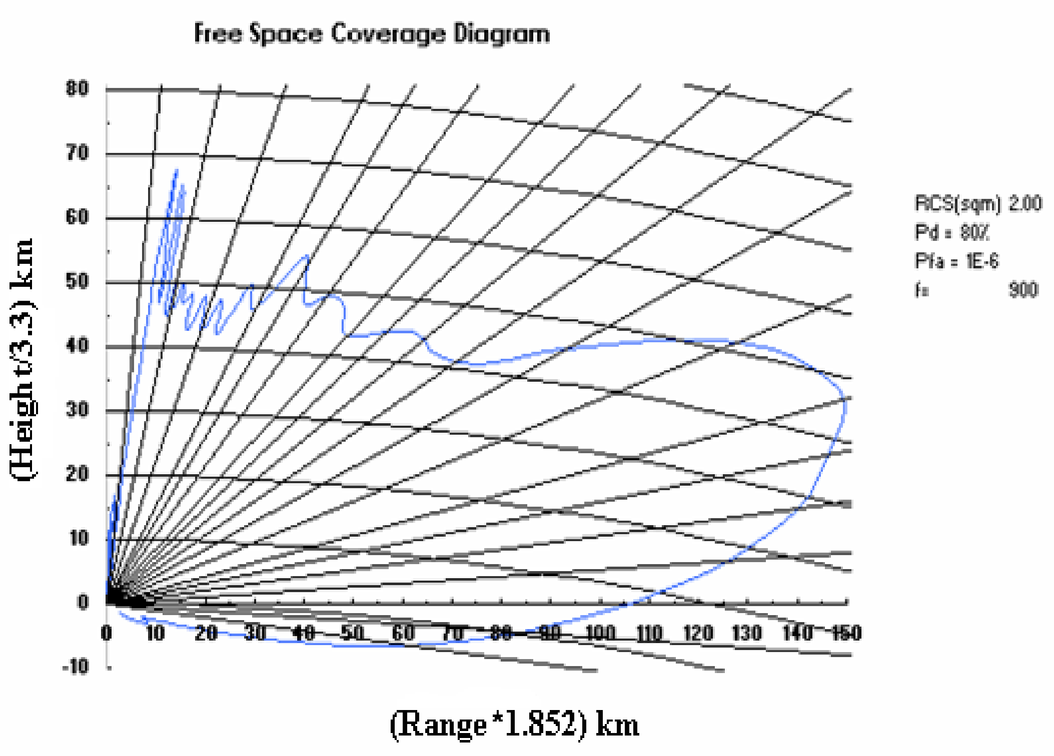

Figure 4: Transmit Beam Coverage for RCS = 2 s.q.m, f = 900MHz

2. Also Figure 5 shows the results of the four coverage obtained in this work; the TX Transmitter, Fan, Intermediate and Pencil beams. The pencil beam coverage gives maximum range of 296.32 km, with maximum height of 13.64 km. The Fan coverage has a maximum range of 162.976 km, and the maximum height is 27.27 km. For the Intermediate coverage, the maximum range is 240.76 km and the maximum height is 18.18 km. It is obvious that the maximum range of the pencil coverage is greater than that of the Fan and the Intermediate coverage. But the Fan coverage has maximum height of 27.27 km which is greater than that of the pencil and Intermediate coverage.

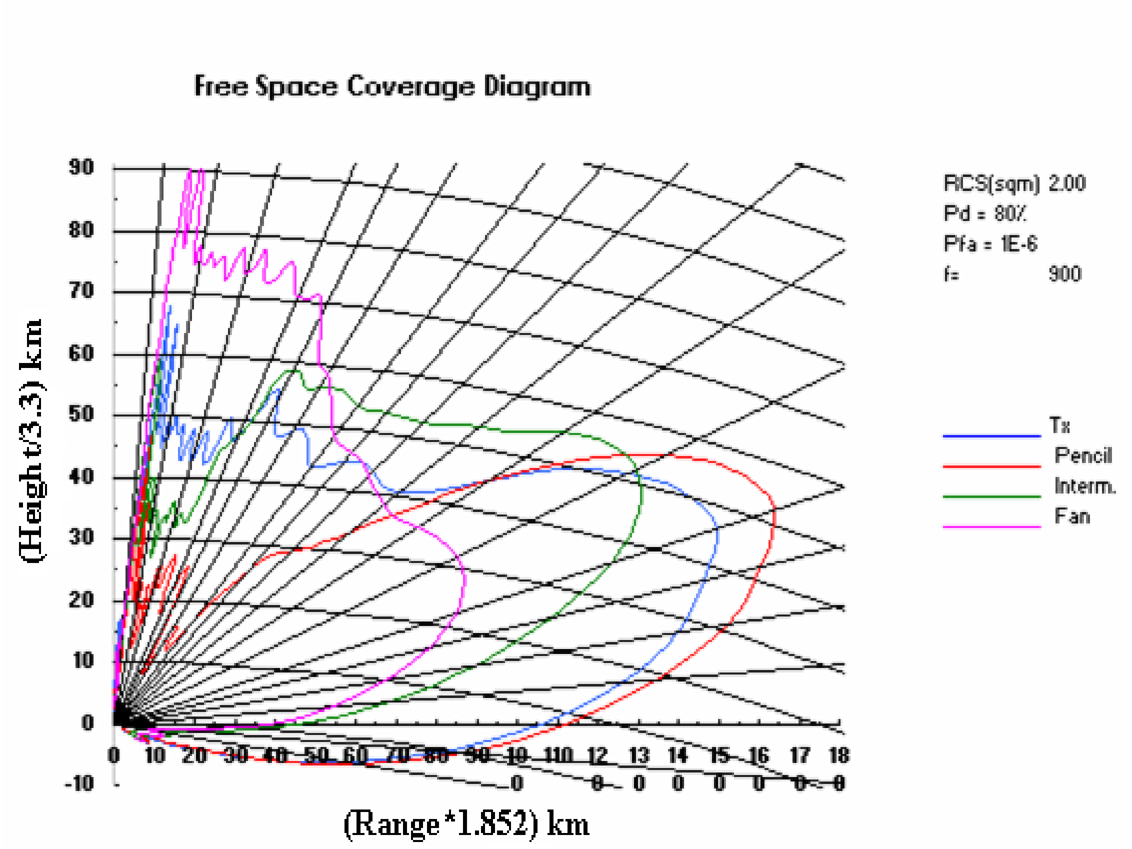

Figure 5: Different Multi-Simultaneous Beams radar coverage RCS = 2 s.q.m, f = 900MHz

3. 5 m^2 RCS: In this case, the radar cross section is taken to be simulated for the Intermediate target which is equal to 5 m^2. The radar parameters are the same as in that of 2 m^2 where the transmitting frequency is 900 MHz, P_d=80% and $P_{fa}=10^{-6}$. The results for this case are shown in Figures 6 to 9 of the different beams, Intermediate beam coverage, Fan beam coverage, Pencil beam coverage and radar Transmit beam coverage, respectively, and it gives different maximum ranges and heights for different coverage.

For the pencil coverage, the maximum range is increased to 360.8 km and the maximum height is 17.27 km which is greater than that obtained when the radar cross section is 2 m^2. Also, for the Fan beam coverage, the maximum range is 188.6 km, and the maximum height is 33.33 km, but in the case of the intermediate coverage the maximum range is measured to be equal 300 km and the maximum height is 22.42 km. It is clear that the intermediate coverage has intermediate maximum range which is equal to 300 km which is less than the 370.4 km maximum range for the pencil coverage case and greater than the 200 km maximum range which is obtained for the Fan coverage case. Also, the maximum height for the intermediate coverage is intermediate between the pencil and the Fan coverage, the maximum height in the intermediate coverage is 22.42 km which is greater than that obtained for the pencil coverage which is 17.27 km and smaller than that obtained in the Fan coverage which equals to 33.33 km.

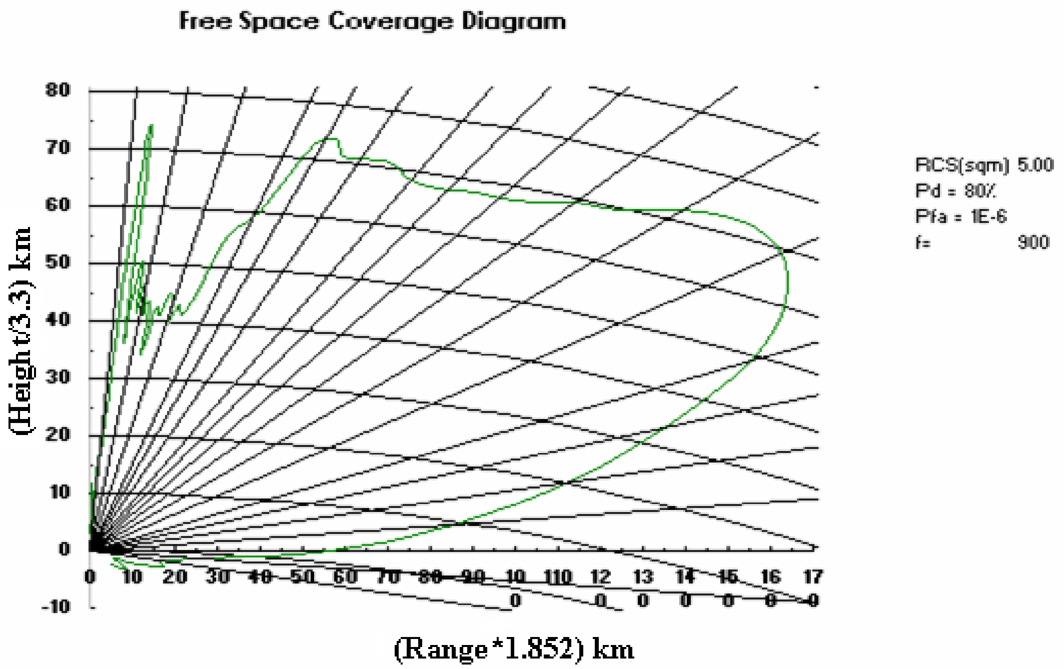

Figure 6: Intermediate Beam Coverage for RCS = 5 s.q.m, f = 900MHz

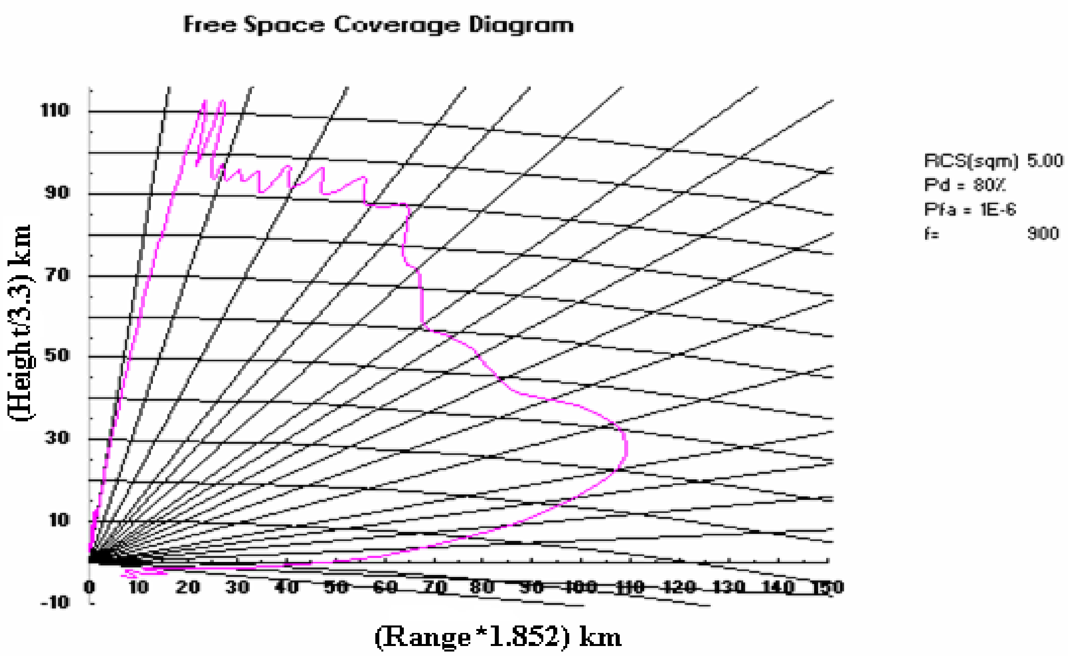

Figure 7: Fan Beam Coverage for RCS = 5 s.q.m, f = 900MHz

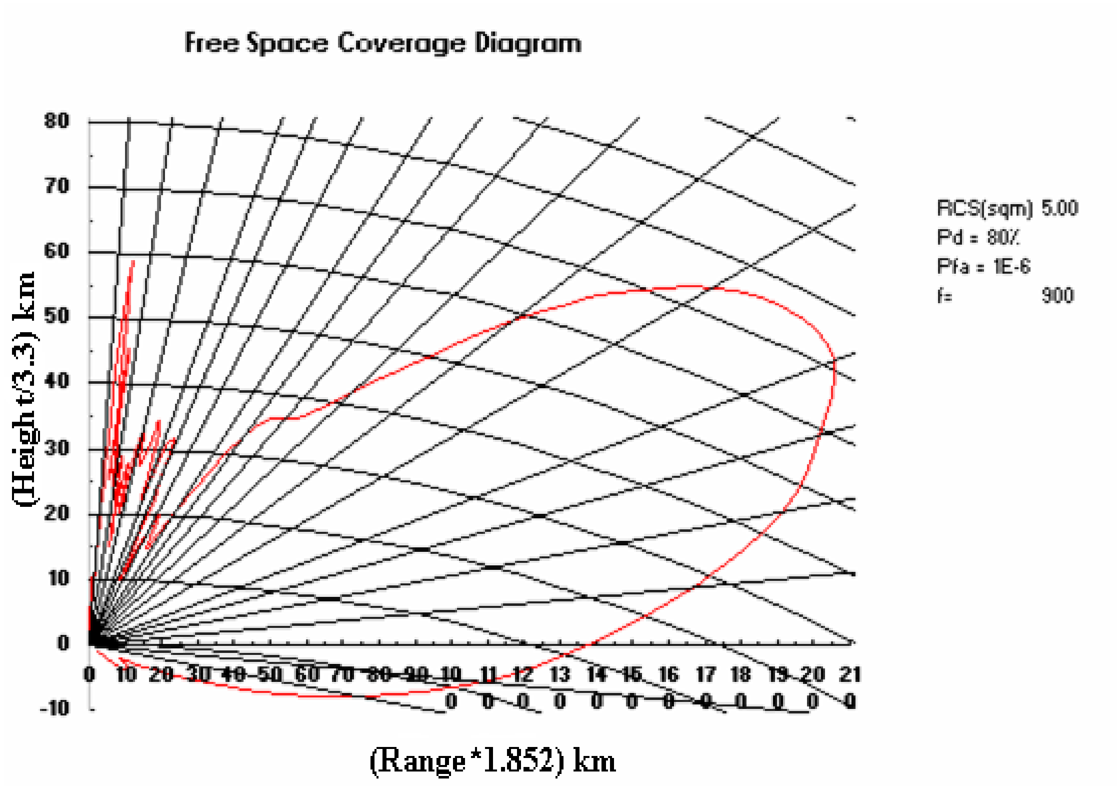

Figure 8: Pencil Beam coverage for RCS = 5 s.q.m, f = 900MHz

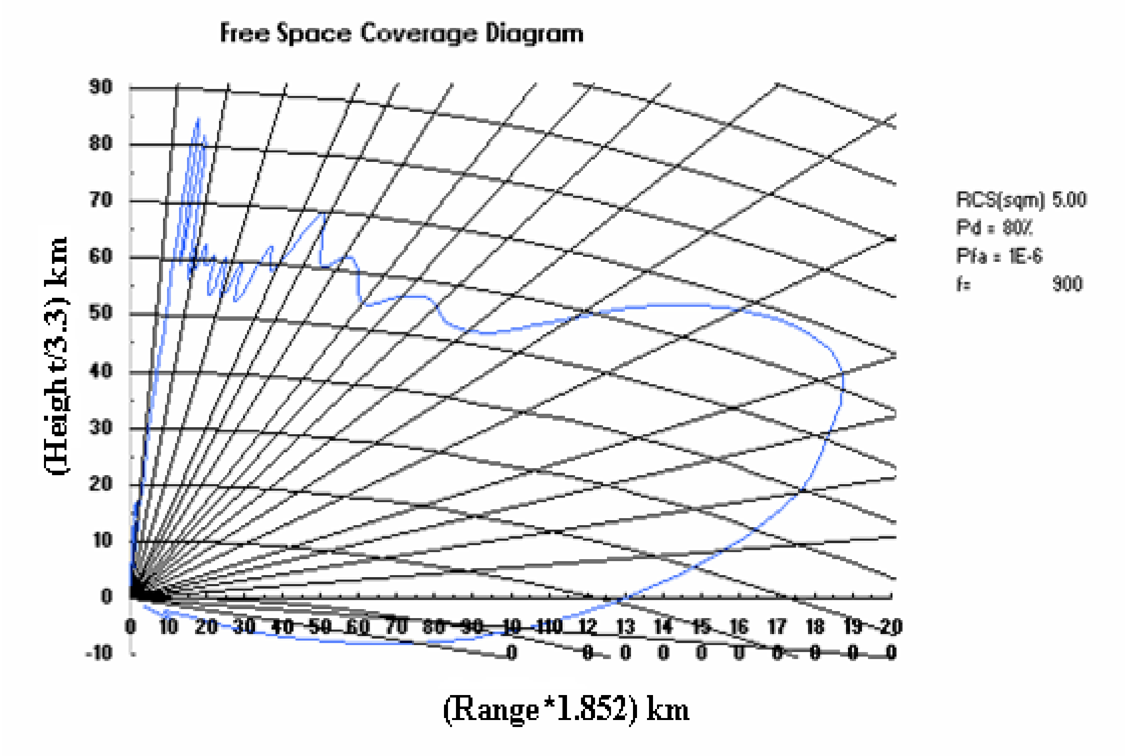

Figure 9: Transmit Beam Coverage for RCS = 5 s.q.m, f = 900MHz

5.1.2 Different Transmitting Frequency

Transmitting Frequency = 900MHz

In this case the four coverage are obtained where the transmitting frequency is 900 MHz and the radar cross section is 2 m^2, the P_d = 80% and the $P_{fa}=10^{-6}$. The results obtained for this case are shown in figure 5. The maximum range in the case of the pencil beam equals to 296.32 km, while the maximum range for the case of Fan coverage is 162.98 km, and it is increased to 240.76 km for the intermediate coverage case.

Transmitting Frequency = 1300MH

In this case the transmitting frequency is changed to be equal to 1300 MHz, and the four beams together are shown in figure 10. The radar parameter are the same as that mentioned for the frequency of 900 MHz, i.e. the radar cross section is 2 m^2, the P_d=80% and $P_{fa}=10^{-6}$. In this case, it is clear that the maximum ranges and maximum heights for different coverage are reduced so much when compared with that obtained for the transmitting frequency of 900 MHz. The maximum range for the pencil coverage is 250 km which is smaller than 296.32 km when the frequency is 900 MHz, also the maximum height in the pencil coverage is 12.12 km which is also less than 13.64 km when the frequency is 900 MHz For the Fan coverage case, the maximum range is 133.34 km which is also smaller than the 162.98 km for the case when 900 MHz was used. The maximum height is reduced in this case to 22.42 km, because it was 27.27 km when the frequency was 900 MHz. Also, the maximum range in the case of the intermediate coverage is reduced to 200 km instead of 240.76 km using frequency of 900 MHz. The maximum height becomes 15.15 km when the frequency is 1300 MHz and it is smaller than 18.18 km when the frequency is 900 MHz. For this case of transmitting frequency = 1300 MHz, different beams are obtained as shown in figure 10 for RCS=2m^2, and figure 11 for RCS=5m^2.

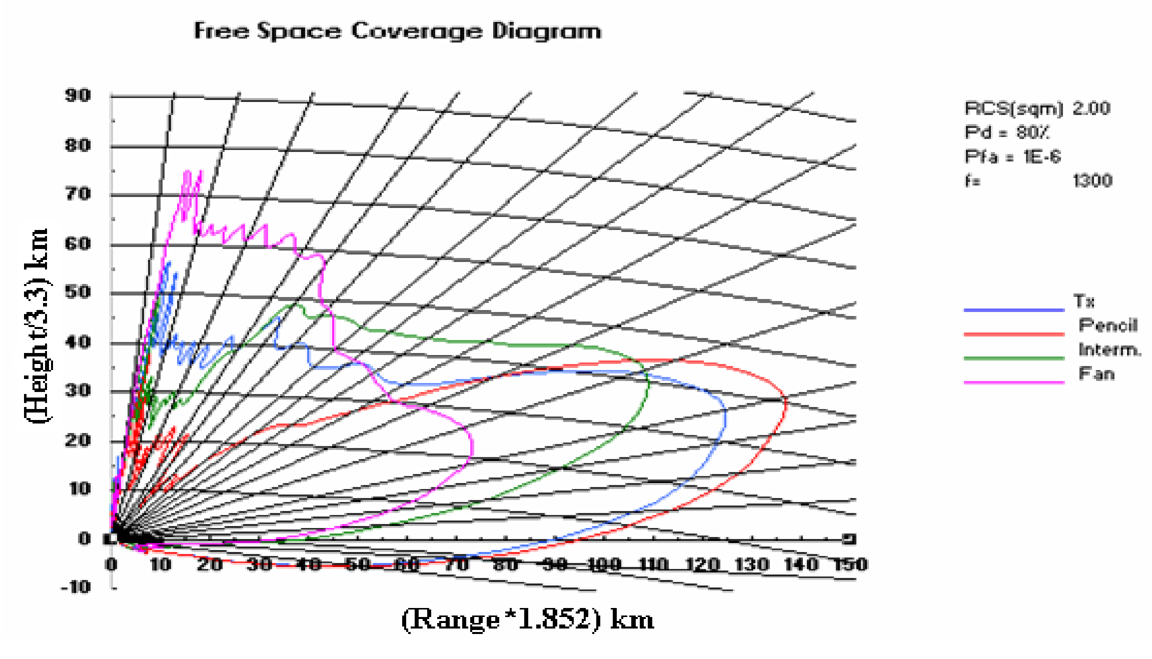

Figure 10: Multi-Beams for RCS = 2 s. q. m and transmitting frequency = 1300MHz

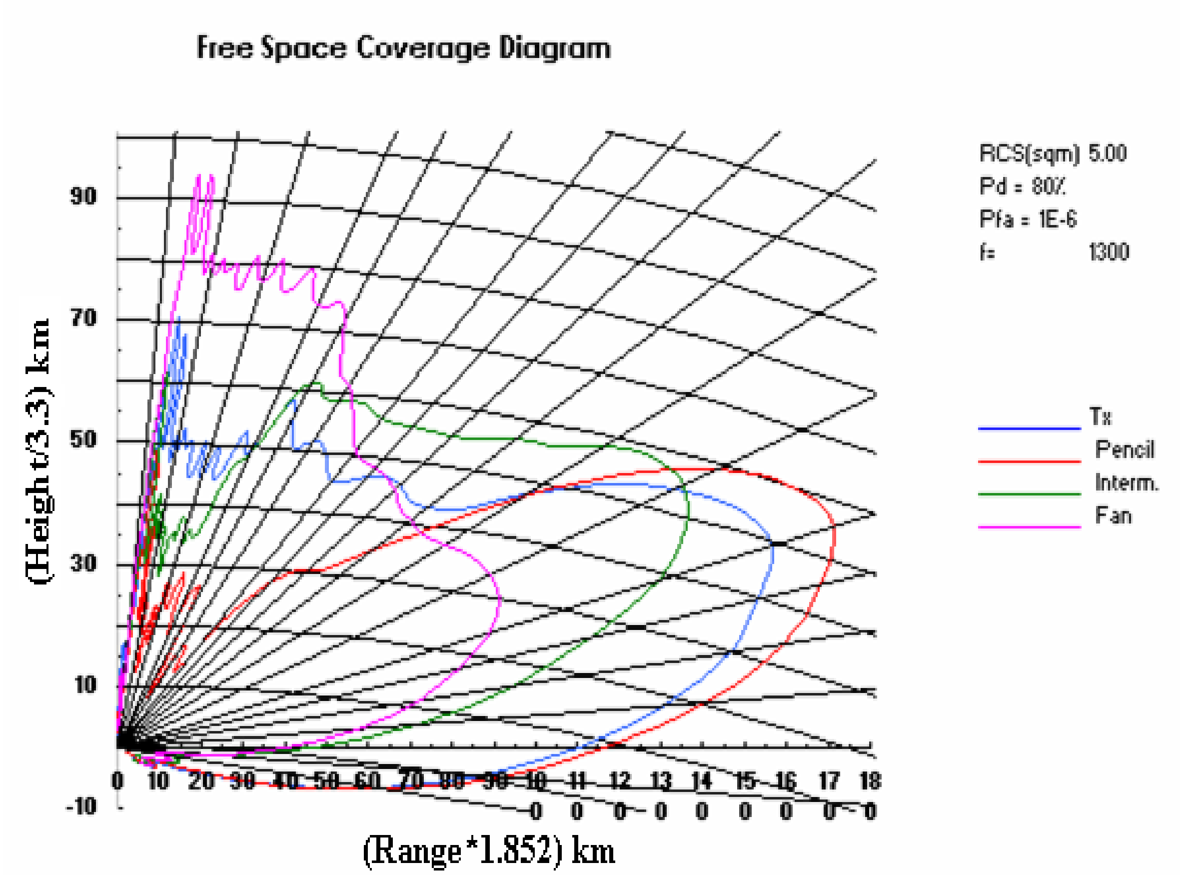

Figure 11: Multi-Beams for RCS = 5 s. q. m and transmitting frequency = 1300MH

6. Conclusion and Future Work

From the obtained results it can be concluded that:

A planner array and beam forming and beam shaping techniques are introduced in order to shape and forming the simultaneous –multi-beams radar with different beams such as Pencil, Fan, Transmitte and Intermediate coverage as shown in Figure 11. The beam forming and beam shaping techniques provide good radar capability and good radar performance in different environmental requirements because it controls the number of required beams and the shape of each beam at the same time depending on the environmental, jamming and clutter scenario.

A. It is concluded that when the transmitting frequency is increased, the maximum range will decrease due to the atmospheric attenuation and when the RCS is increased the maximum range will increase, also because the receiving echo signal is proportional to the target RCS. So by including a properly designed beam-forming network, it becomes possible to feed an array and steer its beams according to the target RCS and transmitting frequency as shown in Figure 11 (Sabah, 1992; David, 1988).
B. The two main features for this study are used in the primary surveillance radar and the secondary surveillance radar of the civilian airports especially in complex terrain and environment where mountains exist in the airport sitting (Robert, 2010).

C. Also it is concluded that the planner array will provide good beam forming and beam shaping techniques and it is possible to implement and construct a smart DSP processor which will choose the appropriate beam according to the target platform and detection scenario for the new technology in addition to save time and cost.

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