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Techniques for Improvements in V.S.W.R and Directive gain of Phased Array Antenna

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Abstract: *Modern electronic systems like Radars, Satellites, trackers, jammers, etc., use Phased array antennas in its transmitter and / or receiver sections, to provide electronically steered beams with high gains. Phased arrays are one of such antennas used for high power applications like jamming. Jammer antennas are mission critical and needs to operate continuously over long period during mission critical operations. Few decades back, parabolic reflectors were widely in use, which need high position time. Many researchers have introduced, phased arrays in radar bands, which are typically narrow band and large in size. But researches have left lot of scope for studies on Ultra Wide Band (U.W.B) phased arrays, which are useful for jamming applications. The radiated powers are in the order of few hundreds of watts, generated by Travelling Wave Tubes (T.W.T)/Solid State Power Amplifiers (S.S.P.A) over wide frequency ranges, typically Bandwidth Ratio (BWR)>3. Voltage Standing Wave Ratio (V.S.W.R) is one of the important parameters to be controlled, otherwise, high cost T.W.Ts / S.S.P.As get damaged due to high reflected powers. Many engineershave followed standard techniques to improve V.S.W.R of ridged horn elements in the array, such as, dielectric loading, stub matching, etc., [1]. Dielectric loading lowers the gain and stub loading reduces the operating bandwidths, thus posing problem in the field of Electronic Warfare. The authors have demonstrated few techniques to improve V.S.W.R [2-3], however, could not achieve V.S.W.R <2.6 in the entire frequency band. Therefore the authors have further carried out the theoretical analysis and practical experiments and proposed a new technique, "Tuning post loading on aperture". The details of the design, simulations and experimental results are presented in this paper.*

Key words: *Band Width Ratio (B.W.R), Electronic Warfare, Impedance, Matching networks, Traveling Wave Tubes (T.W.T), Ultra Wide Band (U.W.B)*

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I. Introduction

Electronic Warfare (E.W) systems, operate in thousands of MHz bandwidths, typically 12000 MHz or 16000 MHz or 18000 MHz, are UWB systems [1]. Electronic Support Measures (E.S.M) and Electronic Counter Measures (E.C.M) are part of EW [4-5]. Typically, E.S.M Systems are passive receivers and ECM systems are high power transmitters. The high power is generated through T.W.T Amplifier (T.W.T.A) or Solid State Power Amplifier (S.S.P.A). The transmitting antenna should withstand high power and require excellent matching with output impedance of T.W.T.A and free space impedance (Z_0) of 120π ohms. This leads good V.S.W.R requirement for the antennas over U.W.B frequencies. The author made many experiments and presented different techniques in his earlier papers [2-3]. However, the targeted V.S.W.R of 2.6 could not be achieved with these techniques. Thus another technique, tuning post loading on aperture, has been demonstrated by the authors to achieve the targeted V.S.W.R of 2.6:1. Thus the paper outlines the simulated and experimental results of V.S.W.R in an eight element phased array. Important definitions with respect to Antenna Arrays are given in [5-7].

II. Design And Simulation

The modeling of the design is carried out using C.S.T Studio 2015 on very high performance work station. The simulated model consists of hybrid tapering, aperture smoothening and with tuning post loading. The simulation of one run took approximately 16 hours to converge on 12 core high end processor based work station. A pair of brass wires of 1.4 mm diameter on the aperture is used in the simulation.

In Figure-1 below, V.S.W.R of simulated model shown above is presented. On observation, V.S.W.R has reduced drastically at low frequencies without much effect on higher frequencies. With the addition of a 1 dB high power attenuator, V.S.W.R has reduced below 2.6 over the entire frequency range, which is target for V.S.W.R.

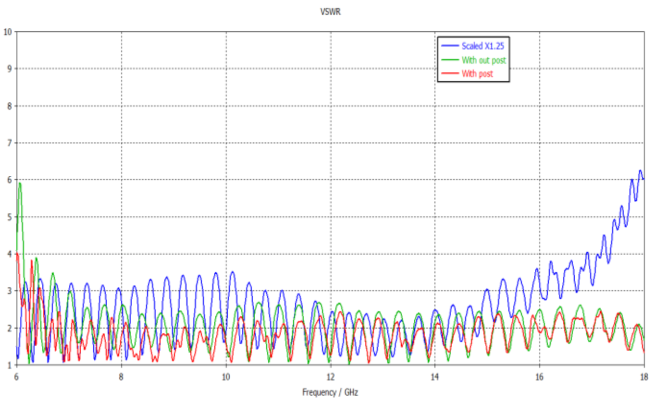

Figure-1: Simulated V.S.W.R with Hybrid tapering, aperture smoothening and tuning post loading on linear horn array

The simulated gain at one port of 8 element array is 14.05 dBi at 6 GHz. The radiation patterns in Azimuth and elevation planes of 8 element arrays are shown at Figure-2.

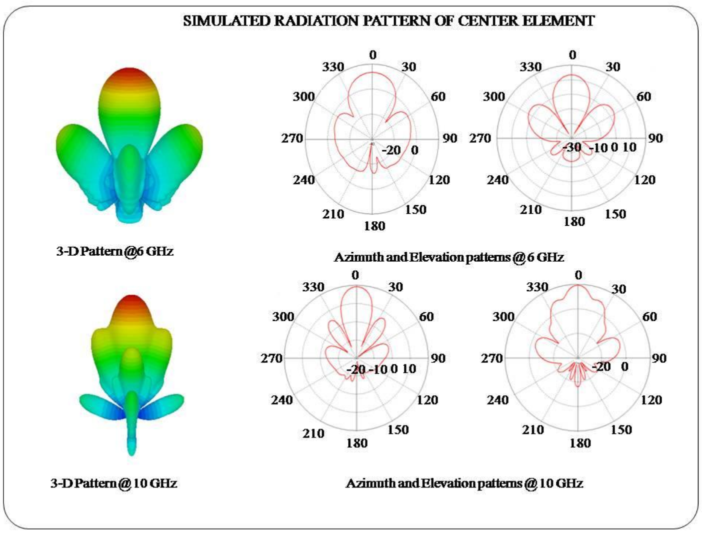

Figure-2: Simulated Array radiation pattern Hybrid tapering, aperture smoothening and tuning post loading on aperture of phased array antenna

III. Prototype Fabrication & Results

The antenna array with eight elements is fabricated, out of which four elements are fabricated with the above techniques i.e., hybrid tapering, aperture smoothening & tuning post loading and the remaining elements are fabricated without these techniques. The antenna elements are fabricated using high end C.N.C machine to achieve the required accuracies in the dimensions. The SMB connector is used for terminating the output of each antenna element. Stringent assembly procedures are followed for fabrication of the antenna. The elements are then assembled using proper screws and washers.

IV. Experimental Results

The V.S.W.R is measured with 2-port Vector Network Analyzer (V.N.A) Model No. N 5232A of M/s Key-sight and the radiation patterns are measured using anechoic chambers, equipped with instrumentation installed by M/s Orbit FR, Israel. MiDAS antenna measurement software is used for taking the radiation patterns of these antennas. The measured V.S.W.R data for one port is shown at Figure-3. Radiation pattern for 6 GHz and 10 GHz is shown at Figure-4 and 5 respectively.

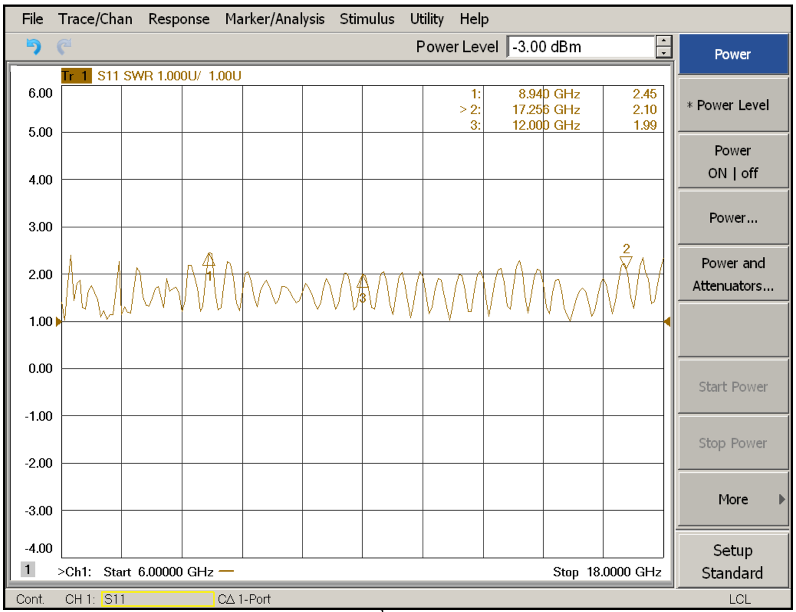

Figure-3: V.S.W.R plot – 5th element in the 8 element array

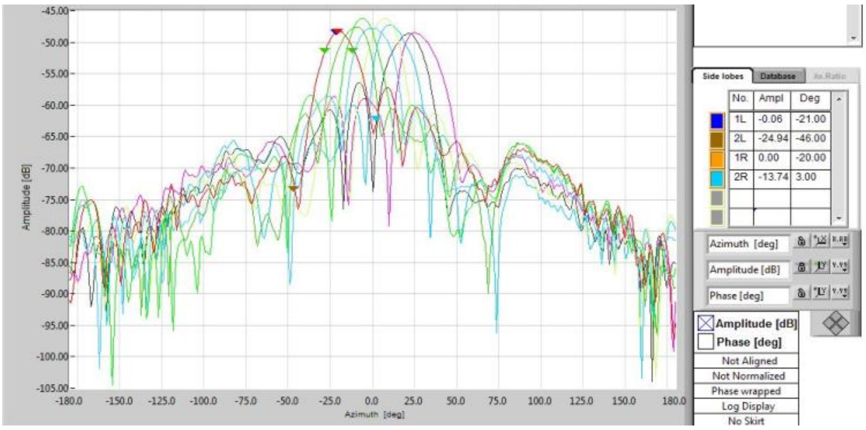

Figure-4: Radiation pattern of 8 element array (6 GHz, HP)

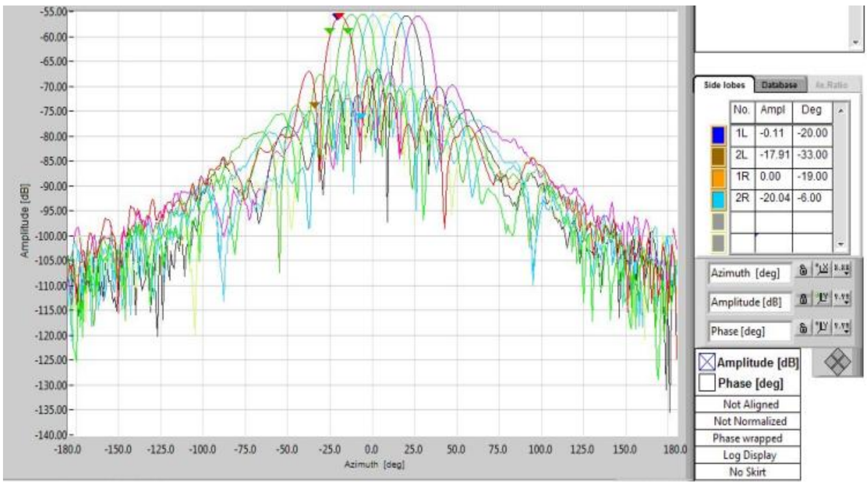

Figure-5: Radiation pattern of 8 element array (10 GHz, HP)

The gain of the array is measured as 14.45 dBi and is 0.4 dB higher than specified.

V. Conclusion

A phased array antenna with eight elements using hybrid taper (Linear and elliptical impedance taper), aperture smoothening and tuning post loading is simulated, manufactured and tested. The simulated and measured results are in agreement over 6 to 18 GHz.

Acknowledgement

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