Measured Transmit Nulling Performance in Wideband Arrays

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***Abstract*— Modern radar systems often incorporate the ability to form nulls in the antenna transmit pattern. Transmit nulls can be used to suppress the returns from point clutter sources greatly and to reduce interference with neighboring emitters. To implement a transmit nulling capability, one practical technique is to provide independent phase control at each element of a phased array antenna. However, for legacy radar systems or for systems with reflector antennas, an alternative hardware approach is necessary. These architectures can be modified to provide a transmit nulling capability by placing an auxiliary antenna with independent phase and amplitude control in the vicinity of the main antenna. The auxiliary antenna forms a null in the far-field radiation pattern of both antennas by creating a signal equal in amplitude but 180 degrees out of phase with the main signal at the null location. The null depths achieved using the auxiliary antenna architecture are sufficient for narrowband applications but degrade when the transmit signal is wideband. This paper describes the measured improvements in wideband nulling performance made possible by an auxiliary antenna that has a tapped delay line (TDL) placed behind the antenna. The TDL affects the frequency response of the signal radiated by the auxiliary antenna and can be used to maintain a deep spatial null at a precise location over a wide signal bandwidth.**

I. INTRODUCTION

Typically, transmit nulls are generated by precise phase (or amplitude and phase) control at the element level [1]-[4]. But, in most legacy radar systems, amplitude and phase control is not available at the array element level. Instead, to form spatial nulls in the transmit pattern of the antenna, an auxiliary antenna with independent phase and amplitude control can be placed in the vicinity of the main antenna. This antenna creates a signal at the desired null location in the far field which is equal in amplitude but 180 degrees out of phase with the signal from the main antenna. When the signals from the auxiliary antenna and the main antenna combine coherently in space, a null is created in the desired direction. If the transmit signal is narrowband, then one phase and amplitude setting at the auxiliary antenna will suffice to maintain the null in a precise spatial direction. However if the transmit signal is wideband, then an independent phase setting at the auxiliary antenna must be applied for every frequency in the signal bandwidth. To control the frequency response of the signal radiated by the auxiliary antenna a TDL (or arbitrary waveform generator) is inserted in the feed path to the antenna. Figure 1 illustrates a notional radar system architecture with an auxiliary antenna and a TDL with *J* taps. Array architectures with a TDL behind every element have been previously described in [5]-[8].

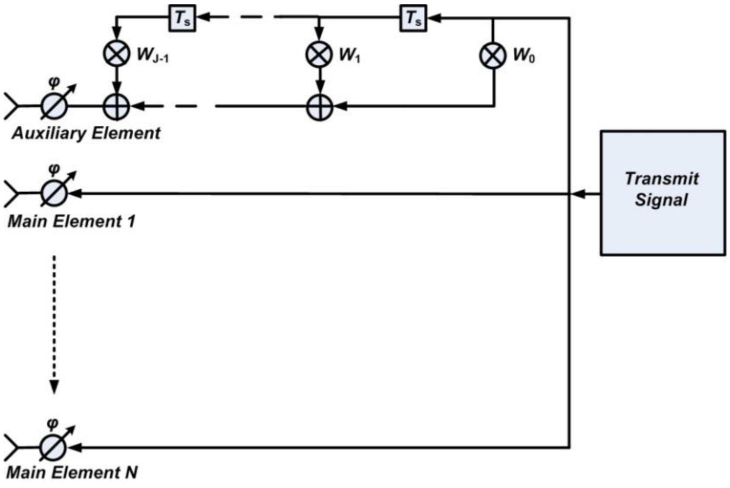

Figure 1. Linear Array with Auxiliary Antenna

II. EXPERIMENTAL RESULTS

Experimental validation of transmit nulling was conducted using a wideband uniform linear array (ULA) in a compact anechoic test chamber. The array elements were driven by a narrowband signal source, and the peak power at the output of a receive horn was measured using a power meter. A low noise amplifier was inserted before the power meter to ensure that the received power within a transmit null was always higher than the noise floor of the power meter. The 4 center elements of the ULA (numbers 5 through 8) formed the main antenna, and one of the edge elements (number 11) was used as an auxiliary. The other array elements were terminated. A variable phase shifter and a variable attenuator were placed behind the auxiliary element to control the phase and amplitude of the auxiliary signal. The phase and amplitude settings were adjusted manually to form a transmit null by minimizing the power measured at the receive antenna. Due to limitations of the test equipment, it was not possible to measure the phase shift or attenuation that was provided to the auxiliary signal. The entire test configuration was placed in a compact antenna range, and radar absorber material was placed along the floor between the antennas to prevent multipath bounce from entering the receiver. The separation between the transmitter and receiver antennas exceeded the minimum far field distance of both antennas. The chamber test configuration is shown in Fig. 2.

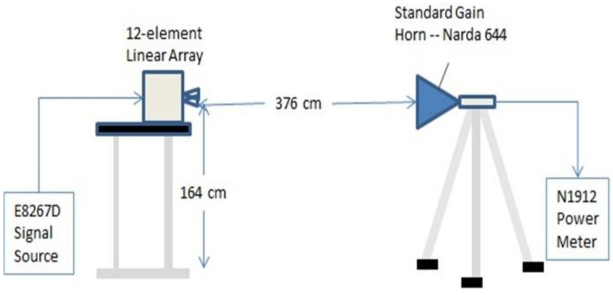

Figure 2. Chamber Test Configuration

The specified bandwidth of the wideband transmit array (Figure 3) is 2 to 4 GHz, and the half-wavelength spacing of the elements corresponds to 3.0 GHz. The specified operating range of the receive horn is 2.6 to 3.6 GHz.

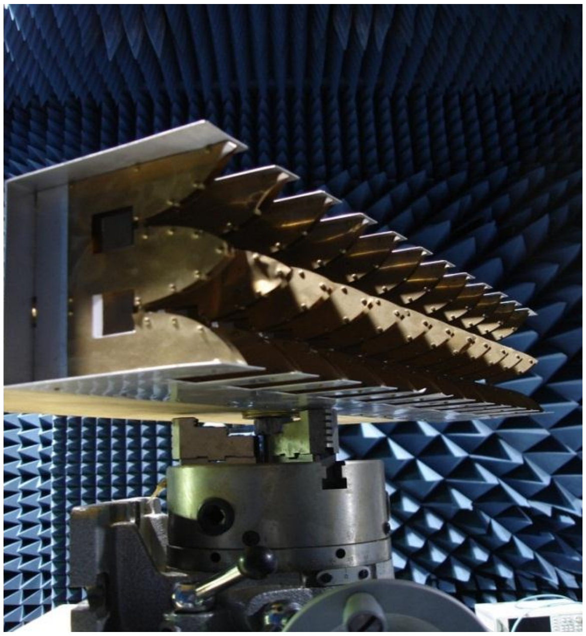

Figure 3. Transmit Array

Figure 4 shows azimuth principal plane cuts of the antenna pattern taken at 2.4, 2.7, and 3.0 GHz. As the transmit frequency changes, the sidelobe null shifts and points in a different direction as the frequency changes. This phenomenon is a central problem when forming spatial nulls with wideband signals [8]. It implies that even if a spatial null exists in a desired direction at one frequency, the null shifts to a new position at different frequencies. To create a frequency invariant null which maintains a constant pointing direction, it is necessary to use the TDL architecture.

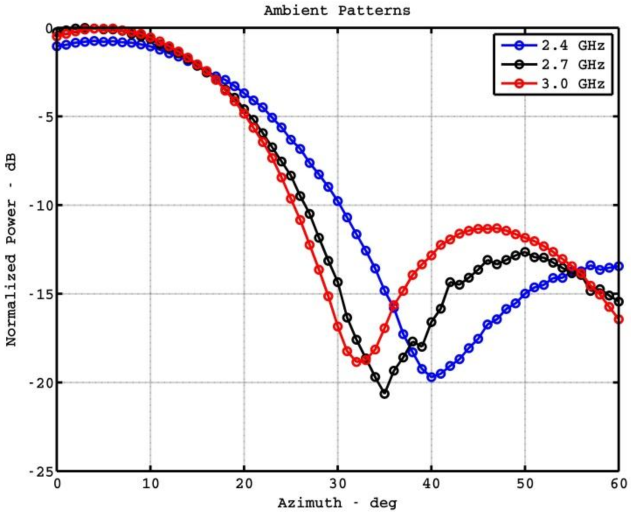

Figure 4. Ambient Antenna Patterns

Using the experimental configuration described, the performance of a TDL architecture was simulated by independently adjusting the phase and amplitude settings of the auxiliary signal to form a null over a set of 30 discrete transmit frequencies from 2.4 to 3.0 GHz. The 30 discrete transmit tones synthesize a 600 MHz wideband spectrum if taken together. The results are shown in Figure 5. The black curve illustrates the null depth as a function of frequency when the auxiliary antenna phase and amplitude settings are optimized for a null at 2.7 GHz and then held fixed for all other frequencies. The red curve illustrates the null depth attainable if independent phase and amplitude weights are set at each discrete frequency, similar to what could be accomplished with a TDL behind the auxiliary element. It is clear from the plot that the attainable null depth using a TDL is deeper and flatter over the entire 600 MHz signal bandwidth than without a TDL.

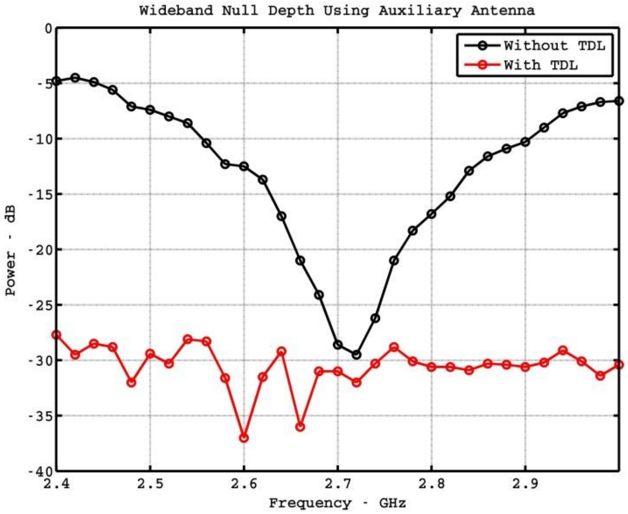

Figure 5. Simulated TDL Performance

Figures 6 and 7 display the measured adapted patterns created when the main and auxiliary antennas transmit simultaneously. Results are shown for 2.4, 2.7, and 3.0 GHz. The phase and amplitude settings of the auxiliary antenna were optimized for each test frequency. Figure 6 illustrates the case where a frequency invariant null was formed at 25 degrees azimuth, and Fig. 7 illustrates the case where a frequency invariant null was formed at 12 degrees azimuth, which is inside the 3-dB width of the main beam. Both figures show that the null pointing direction is held fixed as the transmit frequency varies, as desired. Note that when the null is placed within the mainbeam, the null depth is degraded and the mainbeam is distorted. Table 1 lists the null depths achieved measured relative to the quiescent sidelobe for each of the desired null locations.

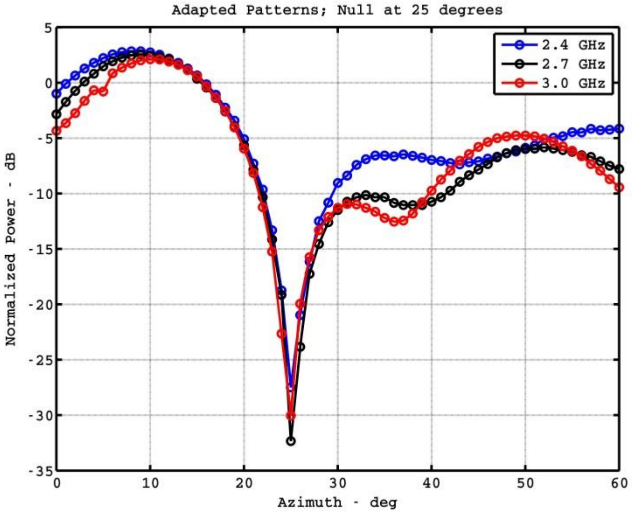

Figure 6. Frequency Invariant Transmit Null at 25° Azimuth

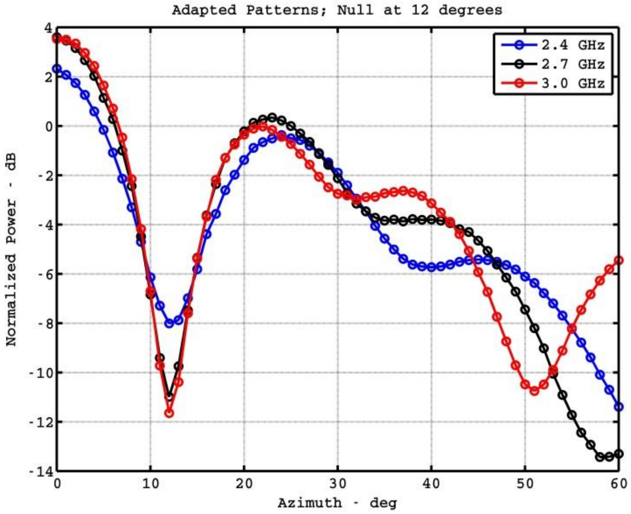

Figure 7. Frequency Invariant Null at 12° Azimuth

TABLE I. MEASURED NULL DEPTHS

Frequency (GHz)	Azimuth Null Location	Null Depth (dB)
2.4	25	21.18
2.7	25	24.00
3.0	25	20.40
2.4	12	6.57
2.7	12	9.83
3.0	12	10.61

III. CONCLUSIONS

The transmit null depths measured using a ULA with an edge element acting as an independent auxiliary antenna show that deep frequency invariant spatial nulls can be created when a TDL is inserted behind the auxiliary element. The TDL serves to control the frequency response of the signal radiated by the auxiliary antenna. With this control in place, the spectrum of the auxiliary signal can be shaped such that the signal from the main antenna is canceled at the desired null location over a wide range of transmit frequencies. Some of the results suggest that deeper null depths may be more difficult to achieve if the desired null is inside the 3-dB width of the main beam. Future experiments will focus on evaluating the variation in peak main beam gain and the spectral distortions induced in the main beam signal for a variety of null solutions.

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