Haleakala Research and Development, Inc.

Plasma Antennas to Reduce Number of Apertures and EMI on Littoral Combat Ships (LCS)

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Characteristics of Plasma Antennas/Arrays

Reduced Number of Apertures and Electromagnetic Interference (EMI)

- Conducts current through ionized gas and not metal.
- Able to transmit and receive from higher frequency plasma antennas to lower frequency ones
  - Not true for metal antennas
- Conforms with a surface.
  - Not true for metal antennas.
- Allows multiple apertures on an LCS to be decreased to fewer or even one aperture by
  - Reducing the number of antennas and antenna farms.
  - Reducing EMI among all antennas on an LCS making lower frequency plasma antennas/arrays invisible to higher frequency plasma antennas/arrays.
  - Reducing and/or eliminating co-site interference
  - Turning off the plasma antennas/arrays and using only those that need to be on

Problems with Legacy Antennas/Arrays

- **U.S. Navy surface combatants employ large numbers of federated RF apertures to perform the following functions**
  - Electronic Warfare
  - Communications
  - Radar

- **Each function has its own aperture, electronics, operator, and logistics/maintenance tail.**

- **The classic stand-alone configuration for legacy RF systems results in Electromagnetic Interference/Compatibility (EMI/EMC) problems that**
  - degrade system performance and
  - increase life-cycle cost for the combatant

Plasma Antenna/Array Technology Improvements to Legacy Antennas/Arrays

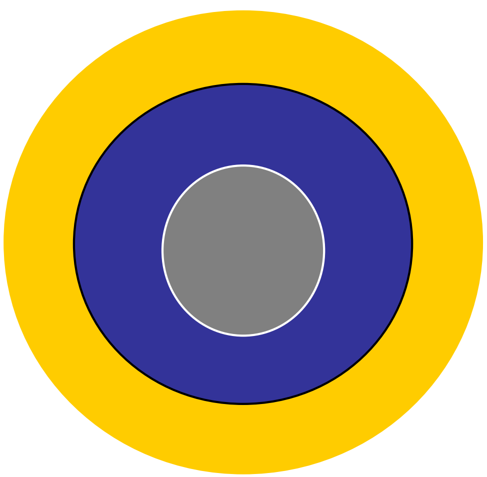
- **Plasma antennas/arrays are able to**
  - reconfigure in radiation patterns, beam width, bandwidth, & frequency.
  - conform to an LCS surface.
  - reconfigure to function as an antenna for
    - Electronic Warfare
    - Communications
    - Radar
  - reconfigure to other apertures for
    - Radio Frequency (RF) multi-functionality support
    - resource management in order to enable
    - greater flexibility to adapt platform capabilities
  - reduce number of antennas and antenna farm on LCS
  - reduce EMI and co-site interference on LCS.
  - increases data rates on LCS.
  - Increases stealth and lowers RCS (Radar Cross Section) because plasma can be lowered in density or extinguished and metal cannot be.

Nested Plasma Antennas

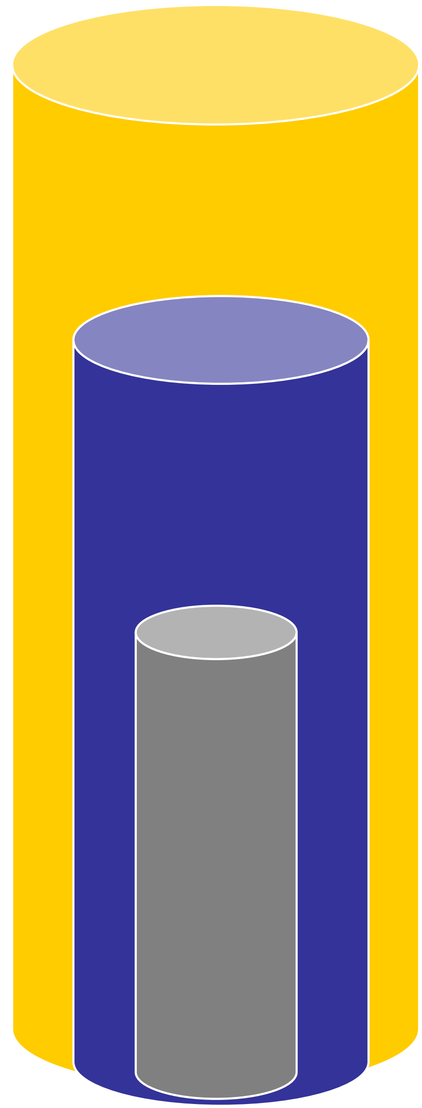
- Higher frequency nested plasma antennas emit higher frequencies which propagate through lower frequency nested plasma antennas
- An antenna nest can be several antennas that are co-located or in a near proximity.
- Bandwidths add
  - Large bandwidths
  - Multiband widths
    - Turn any number or sequence of nested plasma antennas off or on.
- Power adds.
  - Each bandwidth contributes power.
- Nesting antennas means compactness
  - Several plasma antennas are combined into one plasma antenna.
- Maintains impedance matching
  - Each nested plasma antenna is narrow band but adds up to wide band

Nested Plasma Antenna Conceptual Schematic of High Frequency Plasma Antennas Transmitting and Receiving Through Low Frequency Plasma Antennas

Top View



Side View

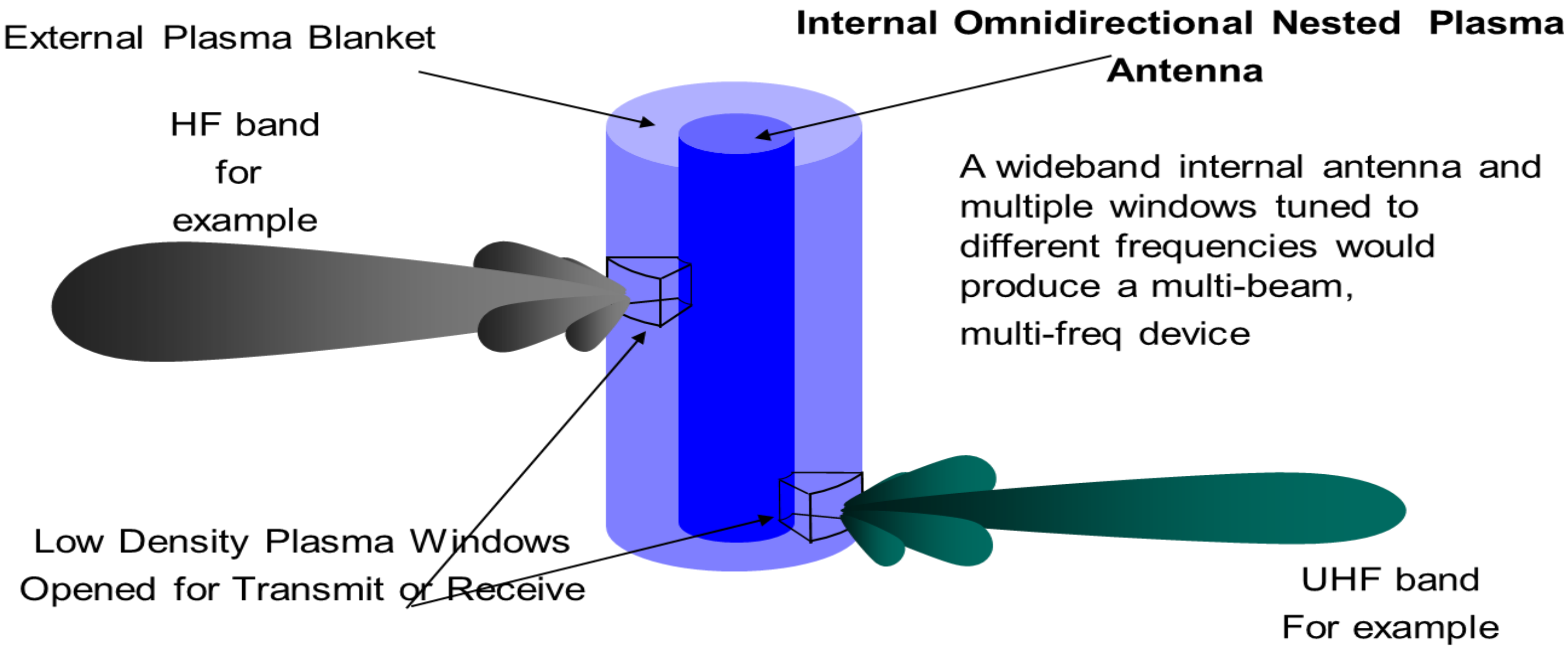


Low frequency plasma antenna

Medium frequency plasma antenna

High frequency Plasma antenna

Tactical Capabilities Plasma Windowing Concept with Plasma Antenna Nesting Combine Apertures on LCS Masts.



Results

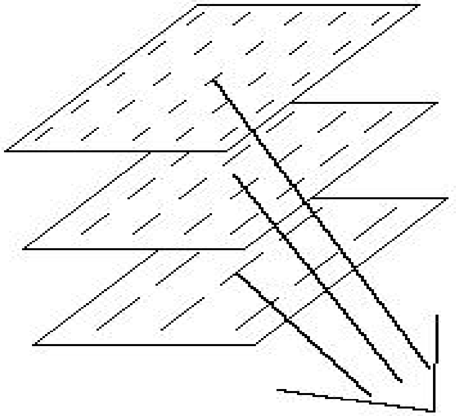
- Nested plasma antenna that combines apertures on LCS masts.
  - More compact
  - Greater bandwidth
  - Multibands
  - High data rates

- High power for increased range and jammers.
- Impedance matched
- Reconfigurable
- Low RCS (Radar cross section)
- Greater stealth.

Stacked Plasma Antenna Arrays

- Metal antenna arrays cannot be stacked
  - Metal from one layer blocks radiation of another layer
- Plasma density from higher frequency antenna arrays is higher than the plasma density from the lower frequency arrays
- Higher frequency plasma antenna arrays emit high enough frequencies to propagate through the lower frequency plasma antenna arrays

Stacked Plasma Antenna Arrays

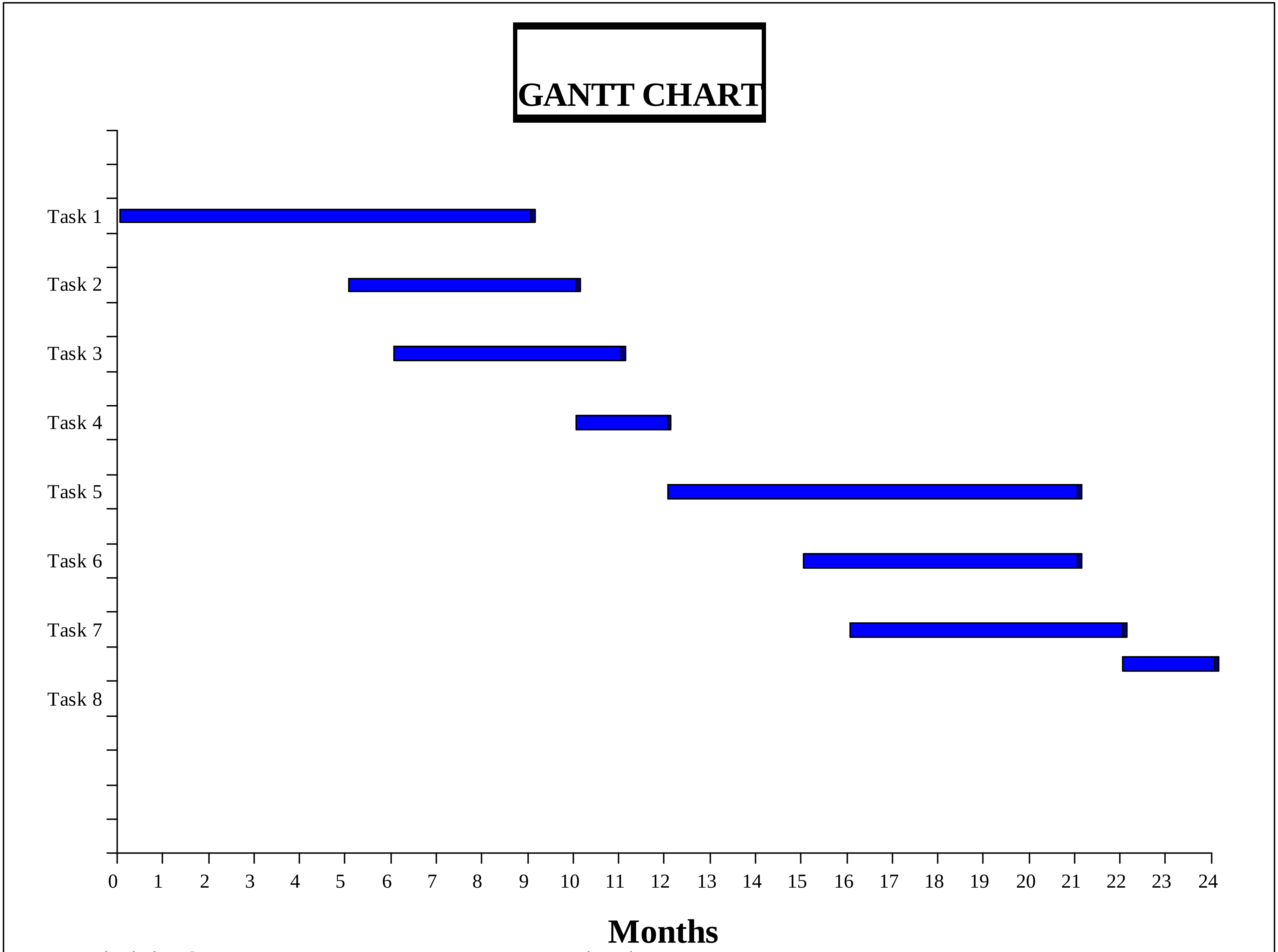


- Greater stealth.
  - Plasma antennas can be turned off to reduce overall RCS (Radar Cross Section)
- Plasma antenna arrays combine multiple antenna arrays into one array.
  - Increases available space
  - Reduces EMI
- Can be conformal on LCS surfaces.

- Higher frequency signals from higher frequency arrays propagate through lower frequency arrays
- Bandwidths add
- Power adds
- Compactness
  - Stacked arrays occupy less space than metal arrays
  - Stacked arrays have smaller RCS
  - Less EMI
- Plasma antenna arrays stacked produces greater:
  - Bandwidths
  - Multiband widths
    - Turn any number of plasma arrays on or off
  - Power for range and jammers
  - Data rates.
- But less
  - physical space
    - helps reduce antenna farm on surface ships
  - RCS (Radar Cross Section)

What it will cost to develop the proposed technology

- Cost to combine two apertures currently on a LCS into one aperture.
  - Task 1. Nest plasma antennas and/or stack plasma antenna arrays.
  - Task 2. Quantitatively show reduction in current LCS antenna farm.
  - Task 3. Quantitatively show reduction in EMI and co-site interference.
  - Task 4. Demonstrate prototype.
  - Estimated cost: $750,000
  - Cost to combine more than two apertures into one on an LCS.
  - Task 5. Nest plasma antennas and/or stack plasma antenna arrays.
  - Task 6. Quantitatively show reduction in current LCS antenna farm.
  - Task 7. Quantitatively show reduction in EMI and co-site interference.
  - Task 8. Demonstrate prototype
  - Estimated Cost: $750,000


GANTT CHART
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Months

Conclusions: Plasma Antennas and or Plasma Antenna Arrays can Reduce the Number of Antennas and EMI on LCS.

- Plasma antennas are:
  - Reconfigurable in:
    - Beamwidth
    - Bandwidth
    - Directivity
  - Steerable without phase shifters and/or phased arrays
  - Resistant to EMI and electronic warfare.
  - Lower in side and back lobes
    - Soft surface effects of plasma
  - Lower in thermal noise than metal antennas
  - Stealth
  - Higher frequency plasma antenna arrays can transmit and receive through higher frequency plasma antenna arrays.
- Plasma antenna arrays can be stacked.
  - Higher frequency plasma antenna arrays can transmit and receive through higher frequency plasma antenna arrays.
- Plasma antennas can be nested.
  - Higher frequency plasma antennas can transmit and receive through higher frequency plasma antennas.
- Plasma antennas and/or plasma antenna arrays can be conformal to an LCS surface.
- Plasma antennas and/or plasma antenna arrays give LCS more stealth and less EMI.
- Plasma antennas and/or plasma antenna arrays give LCS high data rates.

BACKUP

How the Plasma Antenna Technology can Reduce the Number of Antennas and EMI on LCS .

- **Plasma antennas and/or plasma antenna arrays are reconfigurable in:**
  - Antenna radiation pattern
  - Beamwidth
    - The Haleakala smart plasma antenna has reconfigurable beamwidth.
  - Bandwidth
    - Nested plasma antennas and stacked plasma antenna arrays can be reconfigured from broadband to multiband to narrow band.
  - Frequency
    - Plasma antenna can be reconfigured in frequency by changing the:
      - Plasma density
      - Electrical size of the plasma antenna
      - Turning one or more plasma antennas on in a plasma antenna nest or plasma antenna stacked arrays with the rest off.
      - When several plasma antennas are together for multifunctional tasks, turn only the plasma antenna on for a selected frequency or function and leave the rest off.
- **Plasma antennas and/or plasma antenna arrays can be conformal to an LCS surface.**

Physics of Reflection and Transmission of Electromagnetic Waves through Plasma

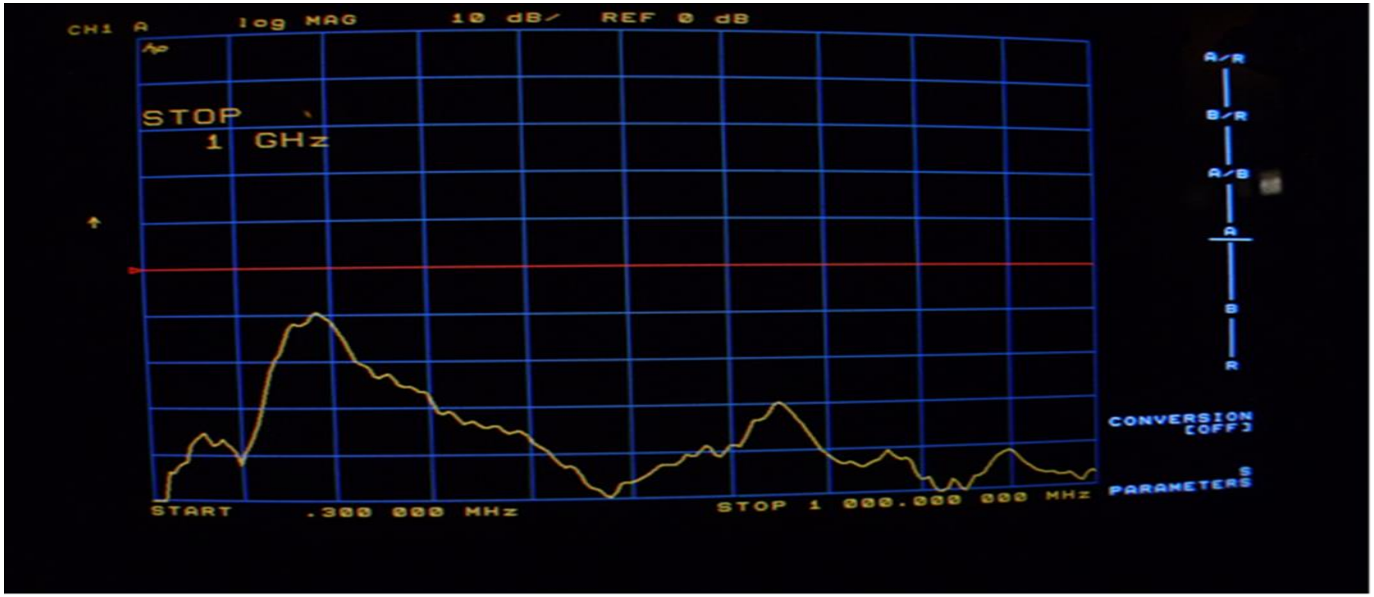
If the incident antenna frequency on the plasma is much greater than the plasma frequency ω_p

The plasma frequency is a natural frequency of the plasma. The lower the frequency of the antenna, the lower the plasma antenna.

Such that $\omega > \omega_p$

the antenna radiation passes through the plasma un-attenuated.

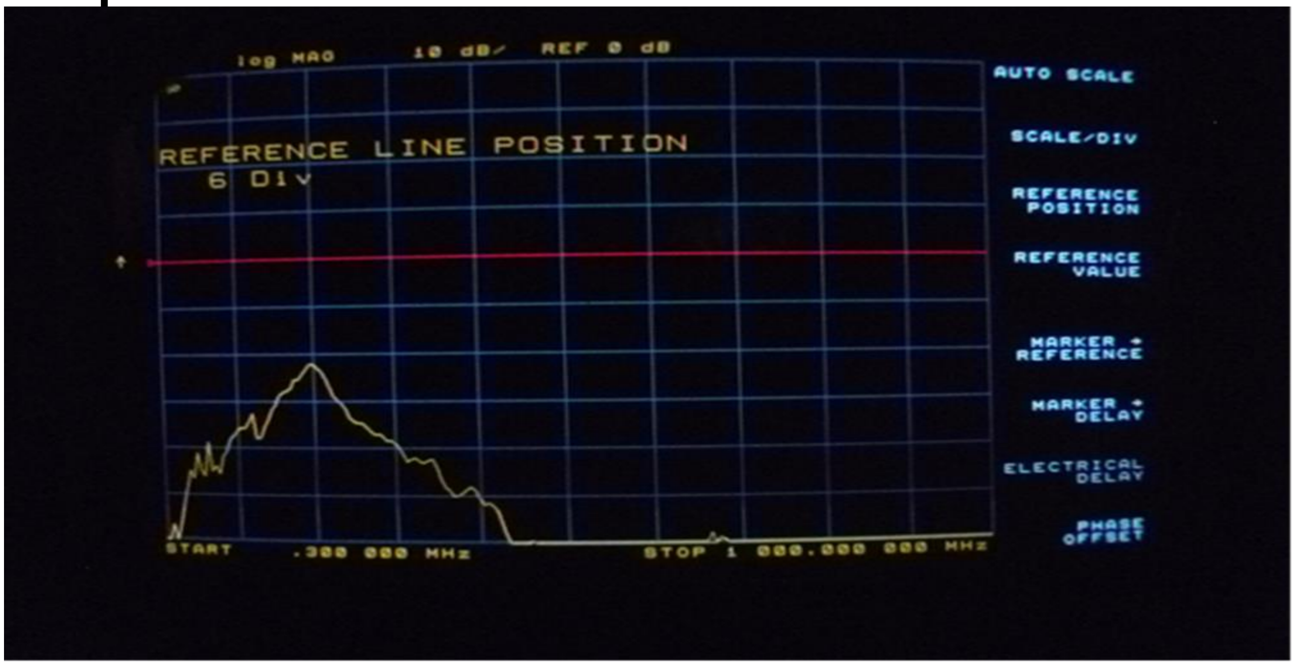
Example of Basic Co-site Interference Reduction Test Represented on this and the Next Slide



Transfer curve for the following conditions.

- Transmitter antenna is an 17 inch vertical metal monopole antenna.
- Receiver antenna is a 19 inch vertical metal monopole antenna.
- Distance between transmitter and receiver rods is 10 inches.
- Span of 0.3 MHz to 1000 MHz.
- 10 dBm/div.

Example of Basic Co-site Interference Reduction Test Represented on this and the Previous Slide



- Transfer curve for the following conditions. Note the reduction in received signal above 400 MHz, compared with the metal antenna receiving antenna.
- Transmitter antenna is a 17 inch vertical metal monopole antenna.
- Receiver antenna is a 19 inch vertical plasma monopole antenna with 150 mA DC drive current.
- Distance between transmitter and receiver antennas is 10 inches.
- Span of 0.3 MHz to 1000 MHz.
- 10 dBm/div.